BIOLOGY AND HUMAN WELFARE

PEABODY and HUNT

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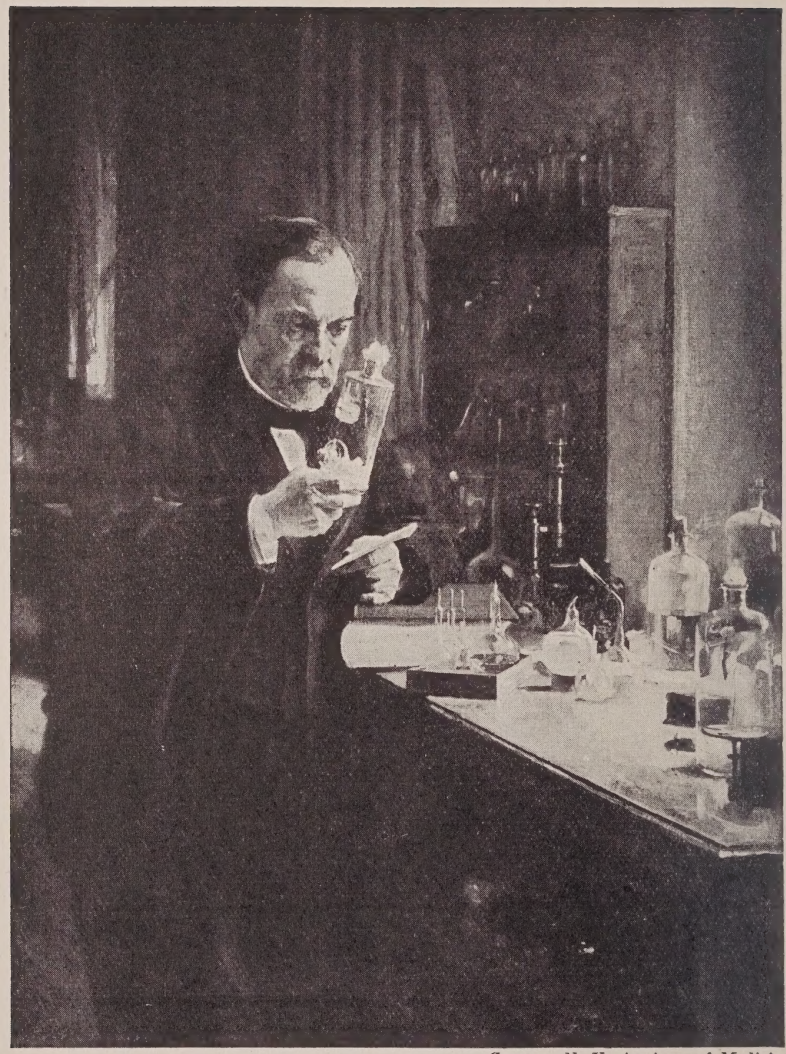

Courtesy N. Y. Academy of Medicine

Louis Pasteur, 1822-1895, carrying on his studies relating to hydrophobia.
"He saved more lives than Napoleon took in all his wars."

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BIOLOGY
AND
HUMAN WELFARE

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PREFACE

Twenty years ago, the authors, in common with many other earnest teachers of biology, became convinced that much more emphasis should be placed on the *functions* of living organisms as contrasted with their structure and that a *comparative study* should be made of plants, animals, and the human body. These two aims were prominent in our *Elementary Biology* published in 1912, in which Part I was devoted to plants; Part II, to animals; and Part III, to the human body.

Biology and Human Welfare represents the development of our ideas, based on the observation and experience of ten years and more since the publication of the earlier book, of the best means of realizing these aims. This is a new book, made on a new plan of organization, with distinctive features, some of which are as follows:

1. We have become convinced that *a given function, for example, digestion or respiration, can be presented more effectively by considering in turn how the process is carried on in plants, in animals, and in the human body than by studying plants, animals, and man as separate units and completing the study of one before taking up the study of the others.* Adolescent boys and girls are most interested in those facts and principles of biology that relate closely to themselves. Therefore, to defer a discussion of human biology to the last part of the course results in a distinct loss of interest on the part of the pupils and prevents the immediate and effective application to human life of the various principles derived from a laboratory study of plants and animals. In studying

the special function in the three spheres, boys and girls are led to see the essential likenesses in the work done by all living things rather than relatively unessential differences in structure.

2. *The dominating purpose throughout this book is to show the intimate relation of biological science to human welfare.* This has been the guiding principle both in the selection of topics and in the method of treatment. An examination of the Table of Contents will show that in Part I we have discussed our lifeless and living environment; in Part II, the nutritive and reproductive functions of living organisms; in Part III, plants and animals that are specially related to human welfare. In Part IV we have grouped certain chapters relating to the functions of three groups of animals and certain topics relating to the human body which may well be studied if time allows, but which we do not consider so important for beginners as the topics treated in Parts I, II, and III.

The field of biology is so large and some of its problems are so difficult that a wise selection of topics must be made if a text is to attain its maximum usefulness. Consequently, some topics that are often found in secondary school texts, but that are more suitable for discussion in advanced courses, have been omitted. Among these may be mentioned Mendel's laws, theories of evolution,[1] and mitosis. On the other hand, topics of everyday interest and importance, for example, vitamins, insulin, and the newer discoveries relating to health and disease, have been included. The wise and

[1] "The prominent evidences of relationship suggesting evolution, within such groups as the decapods, the insects, and the vertebrates, should be demonstrated. A few facts indicating the struggle for existence, adaptation to environment, variations of individuals, and man's selective influence should be pointed out; but the factors of evolution and the discussion of its theories should not be attempted." — Quoted from the syllabus in advanced zoology published by the College Entrance Examination Board and the New York State Department of Education (1921). This syllabus is based upon the report of a committee of the American Society of Zoologists, Eastern Branch.

enthusiastic biology teacher can do much to arouse interest in discoveries like these that mean so much for human welfare.

The book includes more material than can be taught successfully in a single year under ordinary conditions; hence each teacher is free to select those topics that best fit the needs of the pupils he is instructing. We have indicated our judgment as to the relative importance of the topics not only by the grouping referred to above, but also by the use in the text of smaller type for topics that may be omitted.

3. *The material of the book has been carefully tested in the classroom.* For five years we have supplied in mimeographed form text and laboratory outlines for the course given to each of the students who studied biology in the high schools in which we teach. In this way we have been able to profit by the criticisms and suggestions of thousands of students and more than thirty teachers of biology. Term by term we have modified this material, adapting it ever more closely to varying conditions of instruction.

4. *Laboratory work is most important in arousing the interest of pupils and in fixing in their minds essential facts and principles.* We have chosen for laboratory study plants and animals that are available in most parts of the country. The laboratory exercises have been included in the body of the book, because they constitute an essential part of the course and because they are more convenient for use here than they would be if placed in a separate volume or in appendixes.

5. *By the use of the summaries and the review questions* placed at the end of most of the chapters, *pupils can be held to a stricter account for preparing their lessons and for retaining in mind the essentials of each important topic. Diagrams,* also, like those illustrating the carbon cycle (Fig. 130),

the nitrogen cycle (Fig. 203), the energy cycle (Fig. 37), and food manufacture and storage (Fig. 44), have been found to make clearer an understanding of these somewhat difficult but essential processes.

We are deeply indebted to many friends and specialists in particular fields for assistance in reviewing the manuscript either as a whole or in parts. Dr. C. Stuart Gager, Director of the Brooklyn Botanic Garden, Dr. Elsie M. Kupfer, Head of the Department of Biology in the Wadleigh High School of New York City, and Mr. Harold E. Foster, Administrative Assistant in the Morris High School, New York City, have carefully read and criticized the manuscript of the whole book. Dr. W. H. Park, Director of the Laboratories of the New York Board of Health, Dr. Hideyo Noguchi of the Rockefeller Institute, and Dr. F. F. Russell of the Rockefeller Foundation have given valuable assistance in the chapters relating to health and disease. To the following specialists of the United States Government at Washington we are particularly indebted for counsel and help on the chapters named: Dr. E. W. Nelson, the chapter on mammals; Dr. L. O. Howard, on insects; Dr. Harry C. Oberholser, on birds; Dr. Frederick V. Coville and Dr. W. E. Safford, on plants in relation to human welfare; Dr. Hugh Smith, formerly United States Commissioner of Fisheries, on fish; Mr. Thomas H. Gill of the Forest Service, on forestry. Dr. W. A. Bastedo, author of *Materia Medica; Pharmacology; Therapeutics; Prescription Writing* has read the chapters on digestion in man and on beverages and drugs; Dr. George H. Parker of Harvard University, the chapter on how our bodies are controlled; Dr. G. N. Calkins of Columbia University, author of *Protozoa*, on single-celled animals; Dr. Walter H. Eddy, of Columbia University and Major in Charge of Nutrition of the American Expeditionary

Forces in France, on food and diet; Dr. C.-E. A. Winslow of Yale University, on breathing in man and animals; Dr. M. A. Bigelow of Teachers College, on reproduction in plants and animals.

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P. Blakiston's Son & Co., the publishers of Gager's *Fundamentals of Botany*, have been most generous in allowing us to select freely from the wealth of illustrations in Dr. Gager's book. To Henry Holt and Company we are also deeply indebted for permission to use drawings published in Sargent's *Plants and Their Uses*. The World Book Company and Dr. Transeau, the author of *General Botany*, kindly sent us their original drawings for Figs. 77 and 155. To the American Museum of Natural History, the New York Zoological Society, and especially to Mr. Elwin R. Sanborn, its photographer, to the National Audubon Society, the National Tuberculosis Association, the New York Board of Health, the American Red Cross, and to Dr. L. L. Woodruff of Yale University, and Dr. J. F. Williams of Teachers College, we are indebted for illustrations we have been

permitted to use. The many new drawings that appear in the book are almost wholly the work of Mr. B. F. Williamson and Mr. J. de Muro.

J. E. P.

January 14, 1924 A. E. H.

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PART I
INTRODUCTION

BIOLOGY AND HUMAN WELFARE

CHAPTER I

THE WORLD WE LIVE IN

Some questions we might ask about the world in which we live.

How far does this universe of ours extend?

What is the world we live in made of?

How much of the world is alive and how much is lifeless?

Which living things help us and which harm us?

To what extent are we responsible for our health or sickness?

---

1. What is the use of asking questions? Every normal boy or girl is an animated interrogation point. About as soon as he begins to talk, he asks questions — Why? How? When? Where? If he is brought up properly by parents and teachers, he will continue to ask questions all through childhood and youth, and even through manhood and old age. The growing mind is a mind that is continually eager for new knowledge — a mind that asks questions.

In early childhood, the answers to our questions naturally came from our parents, brothers and sisters, or other relatives and friends. But as we grew older, we learned that we could find answers to our questions elsewhere. Of course we learn much from the printed page. But a better method of acquiring knowledge is to study directly the world about

us. "Study nature, not books," said Professor Agassiz (Fig. 1), who was the greatest biology teacher of his time.

Fig. 1. — Louis Agassiz (1807-1873)
The great teacher of biology.

One of the compelling attractions in the study of science arises from the fact that young people are brought by work along this line into more direct contact with the universe of which they are a part. If we wish to study heavenly bodies, we use the telescope; if we are trying to determine the minute structure of plants and animals, the hand lens and compound microscope (Fig. 48) are available; if we are seeking to understand the chemical composition of various things about us, we make use of chemicals, test tubes, and other pieces of apparatus (Fig. 2). Experiments of one sort or another are continually tried, either in the laboratory or outside. In addition to the absorbing interest in carrying on work of this kind, we find that knowledge gained by direct observation and experiment sticks in our minds far more tenaciously than do facts obtained from books or from questions that are answered by others.

Think what we owe to the great scientists who not only asked questions but also worked out the answers to these questions! When the great biologist Pasteur (215) was given the problem of saving the grape crop in France, he asked himself so many questions that, before he had answered

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Fig. 2.—A chemical laboratory

Here the composition of foods is determined and tests are made for their purity.

half of them, he discovered the cause, prevention, and cure of some of the worst diseases that afflict man and animals.

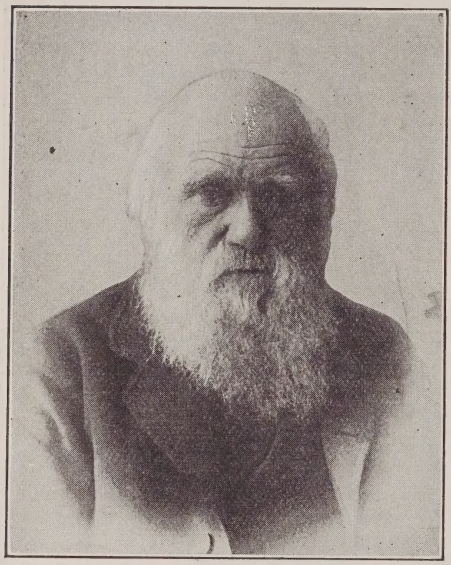

Fig. 3. — Charles Darwin (1809-1882)
For fifty years a painstaking investigator of problems bearing on the theory of the origin of living forms.

Charles Darwin (Fig. 3), to whom the world owes a great part of its modern progress in biology, spent twenty years in getting answers to puzzling questions as to how plants and animals came to resemble and to differ from each other. He then published one of the epoch-making books of all time, *On the Origin of Species*. Even if we can not hope to be Pasteurs or Darwins, we can at least keep our eyes and ears open; we can be constantly learning new and interesting facts; and we may be able to contribute something of real value to the sum total of human knowledge.

I. Our Environment

2. What is meant by our environment. Ordinarily when we speak of our *environment* — by which we mean our surroundings — we think of our home and family, our school and schoolmates, and other things both living and lifeless about us. But we must extend the term "environment" if we are to understand its full significance. A number of homes, schoolhouses, and other buildings with their occu-

pants make up a community, a town, or a large city. Air, water, fuel, means of lighting, parks and playgrounds, the fields and woods, all of which are essential to our health and happiness, are parts of our environment. So too are the trolleys, the railroads, and other means of communication.

When we think of our dependence on the grains, vegetables, meats, milk, and butter, which are furnished by farmers who may live hundreds of miles away, we realize that our environment is much wider than we had suspected. Our clothing is made from the cotton or linen fibers obtained from plants (Fig. 201) that grow in widely distant localities or from the wool, hides, fur, or feathers of animals or from the silk spun by the silkworm (Fig. 238). Distant from most of us too are the coal mines of Pennsylvania, the orange groves of California or Florida, and the spice trees of Africa or India. Since the whole earth, therefore, contributes to our comfort and enjoyment, we may rightly claim it all as a part of our environment.

But further study shows us that, were it not for the rays of light and heat from the sun, all life would cease. Scientists tell us that all the food supply of the world is made by green plants and that these green plants, which are our food factories, can not carry on their work without sunlight (**26**). Hence the sun that is the center of our solar system is a most essential part of our environment.

The sun, however, even though it is 93,000,000 miles away, seems relatively near us when we learn that many of the stars that we see on a clear night, even those that are nearest to us, are in reality so far away that the human mind can not conceive of such distances. Yet all these heavenly bodies are a part of our environment and have to do with human welfare. For instance, the mariner, even

in these days, pilots his course over the sea by observing the sun by day and the stars by night. The daily rise and fall of the tides mainly result from the changing position of the moon with reference to the earth. *Our environment then in its broadest sense extends to the farthest confines of the*

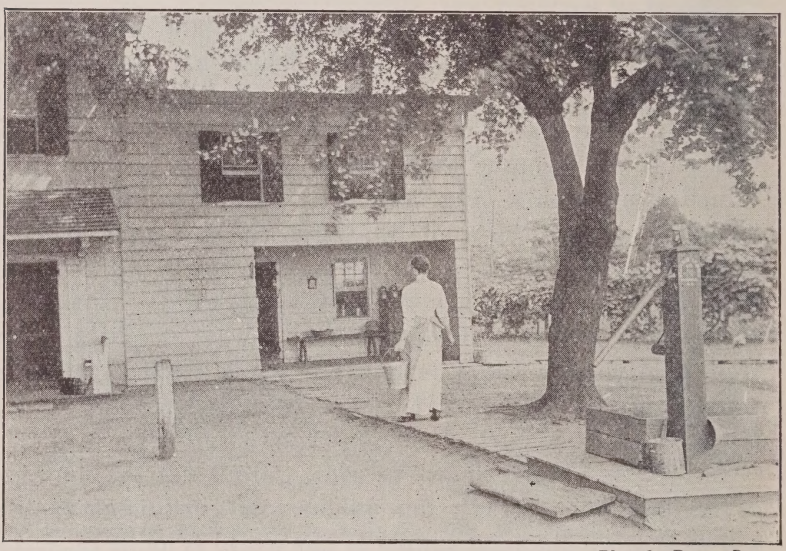

Photo by Brown Bros.

Fig. 4. — Good country environment

Name several respects in which this country environment is far better than that shown in Fig. 5.

universe and includes everything that affects us whether for good or ill.

3. How we can change our environment. Since our lives are affected so greatly by our surroundings, it is important to understand as fully as possible our environment to the end that we may multiply those influences that are beneficial and get rid of those that are harmful. If by bad management we permit house flies to breed, typhoid fever

is very likely to increase, since these flies often carry the germs of typhoid fever on their hairy bodies (**277**). Again, if honeybees are raised in the vicinity of a fruit orchard (Fig. 248), the fruit crop becomes considerably larger because the bees help in fruit production (**269**). Since a farmer can determine whether he will raise bees or flies, vegetables

Fig. 5. — Bad country environment
State several ways in which this slovenly environment could be improved.

or weeds, it is evident that he is responsible largely for the immediate environment in which he lives (Figs. 4, 5). So each one of us is more or less responsible for his surroundings and the more so as he grows older. Even as high-school students we can keep our rooms at home and our desks and lockers at school clean or dirty, and we can see to it that the places we live in are well-ventilated or stuffy. We can and do choose our associates. So we make

the environment in which we work and play wholesome (Fig. 6) or unwholesome (Fig. 7) for body and mind.

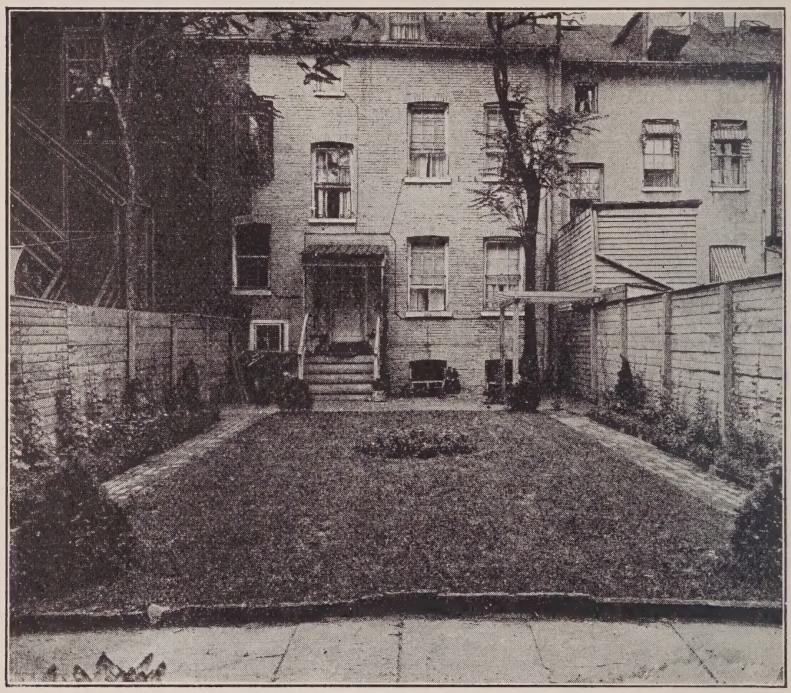

Photo by Brown Bros.

Fig. 6. — Good city environment

Name as many attractive features of this city yard as you can. Can you suggest any improvements?

II. The Air as a Part of Our Environment

4. How we become conscious of the presence of air. A moment's thought will convince us that the part of our environment which is nearest to us and most constantly necessary is the air. Under ordinary conditions we are not conscious of this mantle of air everywhere about us since we do not smell it, taste it, see it, or feel it.

When air is set in motion, however, as on a windy day, we have distinct evidence that it is a substance, especially

Photo by Brown Bros.

Fig. 7. — Bad city environment

What objections would you have to living in sight of surroundings like this? How can such conditions be remedied?

when our hats are blown off suddenly or our umbrellas are turned inside out. Let us see whether we can prove by experiments that an invisible gas like air is as real a substance as are water, wood, and soil. We know that each of these substances occupies space and exerts pressure. Is this true of air also? The following experiments will help us to answer this question.

EXERCISE 1

Does air occupy space? Home experiment.

Invert a tumbler in a glass dish, about three inches deep, containing water, and press the glass down to the bottom of the dish.

1. State what you have done.
2. With what was the apparently empty inverted glass filled?
3. Compare the level of the water inside and outside the glass.
4. What prevents the water from rising into the glass?
5. What proof have you from this experiment that air occupies space.

EXERCISE 2

Does air exert pressure? Home experiment.

Fill a tumbler full of water and cover with a piece of paper, pressing down on the paper with the palm of the hand. Remove the hand and quickly invert the tumbler of water. (It is best to perform this experiment over a sink.)

1. Describe what you have done and state the result.
2. What proof have you that air exerts an upward pressure?

5. What the extent of our environment of air is. Air is one of the most immediate parts of our environment. Not only does it surround our bodies and penetrate our clothing, but it also fills spaces between the particles of soil; it is dissolved in water, for we can sometimes see the bubbles of air collecting on the inner side of a glass of water that has been allowed to stand for a time. Air extends outward from the earth's surface to a distance of perhaps two hundred miles.

At sea level the air is dense enough to press upon every square inch of surface with a weight equal to about fifteen pounds. Scientists have shown that this pressure of the air can support not only the weight of a tumblerful of water but also that of a column of water thirty feet high

or of mercury thirty inches high (Fig. 8) in a pipe that is closed at the top, provided the air inside the tube has been removed.

If we leave sea level and go up on a mountain top or if we ascend in a balloon or an airplane, the height of the air above us becomes less and less, and consequently its weight and pressure becomes less than fifteen pounds per square inch. At a height of several miles the atmosphere becomes so rarefied, that is, so very thin, that aviators find it necessary to carry oxygen to breathe when they ascend to higher levels. A device has recently been invented by which the airplane engine also may be supplied with oxygen in order to ascend still higher.

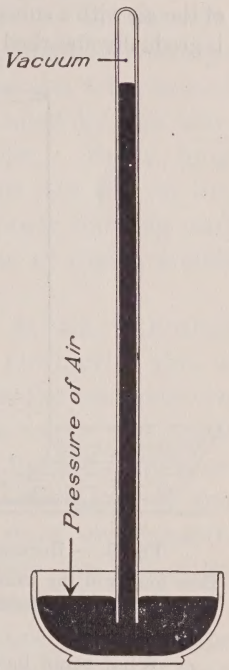

Fig. 8. — Torricellian tube

What does this experiment demonstrate?

EXERCISE 3

Is air composed of more than one kind of gas? Laboratory demonstration.

Fasten a three-inch piece of a good-sized candle to a piece of cardboard about three inches square, and place the cardboard beneath the surface of a dish of clear limewater about two inches deep. Light the candle and quickly invert a pint bottle containing air over the flame, in such a way that only a part of the mouth of the bottle touches the cardboard beneath the limewater (Fig. 9).

1. Describe the experiment, or draw and label the apparatus.
2. What do you note in regard to the flame after a brief time?
3. NOTE[1] (to be copied in the notebook). The substance in the air that causes the candle to burn is *oxygen.*
4. Why does the candle soon cease to burn?

[1] All NOTES should be copied by the student into his notebook and should be enclosed in quotation marks.

5. Gently shake the limewater in the bottle. What change do you note in the level and in the appearance of the limewater inside the bottle?

6. NOTE (to be copied in the notebook). When the candle burns, a substance known as *carbon dioxid* is formed by the union of the oxygen of the air with a substance found in the candle. This gas (carbon dioxid) is gradually absorbed by the limewater and so is removed from the air we are testing.

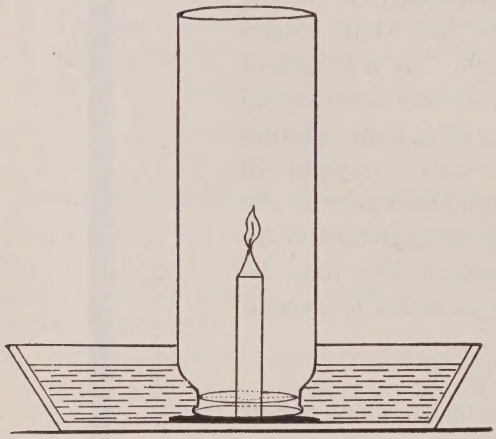

Fig. 9. — Burning candle experiment
How long will the candle continue to burn in the bottle of air?

7. Is all the air consumed by the burning of the candle? How do you know?

8. Press the sheet of cardboard against the mouth of the jar and quickly turn it right side up, without losing any of the gas or liquid. Light a splinter of wood, quickly move the cardboard to one side, and instantly thrust the burning splinter into the gas.

a. Describe what is done.

b. Does the splinter continue to burn?

c. What proof have you that a gas other than oxygen is found in the air? This second gas is known as *nitrogen*.

9. What proof have you, therefore, that air is composed of more than one kind of gas?

6. What the two principal gases found in air are. In ancient times air was thought to be a single substance. Indeed some of the Greek philosophers believed that the universe was made up of four simple "principles," or substances: earth, air, fire, and water. Early in the seventeenth century, however, it was ascertained, as we have

just proved, that the gas which remained in an enclosed space where something had been burned (*e.g.*[1] a candle) could not support burning. The gas now known as nitrogen was then called "destroyed air," and the original air containing oxygen was spoken of as "fire air." It was not, however, until the second half of the eighteenth century, just before the American Revolution, that the true nature of the two principal gases in air was revealed by the celebrated French chemist Antoine Lavoisier. By a long series of experiments he proved that about one fifth of the air consists of a gas, oxygen, which supports burning and that four fifths is made up of another gas, nitrogen, which does not support burning.

7. What other substances are found in air. Another substance found in air is water vapor. Ordinarily this is invisible, like oxygen and nitrogen. When the temperature of the air drops sufficiently, however, the vapor condenses in tiny droplets to form fog (Fig. 10), and further condensation brings down the moisture in drops of rain. If the temperature drops still lower, flakes of snow are formed. That water vapor is present even on a clear day can often be proved by looking at the outside surface of an ice pitcher, for we find it covered with beads of moisture. These drops do not come from the water within the pitcher as many people think. Instead, they are formed on the cold surface by the cooling and condensation of the invisible moisture of the surrounding atmosphere.[2]

In addition to oxygen, nitrogen, and water vapor, air contains still another very important substance but in relatively minute quantities. When the candle was burned

[1] *e.g.* means *for example.*

[2] The presence of moisture in air may be shown even better by the use of a highly polished metal container used in determining the dew point. The advantage of using the highly polished metal surface is that one can see the slightest deposit of moisture.

in the bottle of air, we found that a gas was produced which turned the limewater milky. The name of this gas is *carbon dioxid*. Since carbon dioxid is the only gas that will

Photo by Ewing Galloway

Fig. 10. — Fog, or visible water vapor

Why is the fog in the valley and not on the hilltops?

unite with limewater to form a fine white powder which at first makes the limewater milky, the presence of this gas in ordinary air is easily demonstrated by allowing a dish of clear limewater to stand overnight. On examining this

limewater, we notice fine white particles at the bottom of the dish. This proves that air contains carbon dioxid. Another method of showing that this is true is the following:

EXERCISE 4

To prove that carbon dioxid is present in air. Laboratory demonstration.

By means of a bicycle pump force air for at least five minutes through clear limewater that partly fills a tall bottle.

1. Describe the experiment, state the result, and give your conclusion.
2. Do you infer from this experiment that the percentage of carbon dioxid in a quart of air is large or small?

EXERCISE 5

How may carbon dioxid be formed? Laboratory demonstration.

In order to answer this question it is necessary to secure a bottle of pure oxygen (Fig. 11). This may be done by heating some of the solid substances that contain a large amount of oxygen.[1] A common substance that may be used is chlorate of potash. When bottles of oxygen have been obtained, proceed as follows: Hold some charcoal (which is nearly pure carbon) in a flame until it glows; move the cardboard aside sufficiently to thrust the glowing carbon into the bottle of oxygen.

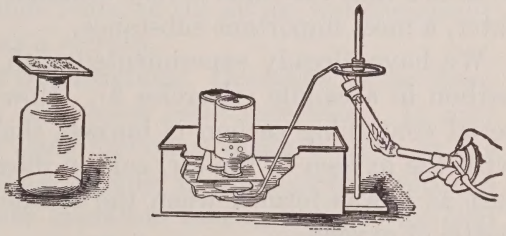

Fig. 11. — Preparation of oxygen

What is driving the water out of the bottle in the center of the picture?

1. Tell what is done with the glowing carbon and describe what happens.
2. Does carbon burn better in air (a mixture of oxygen and nitrogen) or in pure oxygen?
3. After burning a piece of carbon in the bottle of oxygen, remove the

[1] For preparation of oxygen see Appendix II.

cover sufficiently to pour in a small amount of limewater and cover again. Shake the bottle to mix the gas with the limewater. Describe the experiment, and state the change that takes place in the limewater.

4. Of what two substances must this new gas have been formed? Why is it called carbon dioxid?

5. What is one way, therefore, in which the gas carbon dioxid may be made?

8. What some of the sources of carbon dioxid found in the air are. If one were to hold a white porcelain plate in a candle or gas flame, a black substance would collect on the plate. This substance is known as *carbon*. Similarly, when wood is partially burned, charcoal is obtained, which is composed likewise almost wholly of carbon. The black particles in the smoke that arises from any burning substance (*e.g.* kerosene and soft and hard coal) is another evidence that carbon is a very common and, as we shall see later, a most important substance.

We have already experimented with the burning of the carbon in a candle (Exercise 3). Now whenever any material containing carbon is burned, that is, when it unites with the oxygen in the air, carbon dioxid must be formed, just as it was formed when the candle was burned in the bottle of oxygen.

Another source of the carbon dioxid in the air becomes apparent when one breathes through a glass tube into a bottle or test tube partly filled with limewater.[1] The milky appearance of the limewater produced by a single breath shows that a human being must give off a considerable quantity of carbon dioxid in the course of twenty-four hours. Similar experiments with other kinds of living things show that they likewise give off carbon dioxid as long as they are alive.

[1] This experiment should be demonstrated by the teacher (see Exercise 24).

III. Some Terms Used in Discussing Our Environment

9. How elements, compounds, and mixtures differ. Carbon, oxygen, and nitrogen are *chemical elements. A chemical element is the simplest substance that can enter into combination.* Carbon dioxid, as its name implies, is composed of one part of carbon and two parts of oxygen. From the fact that this gas consists of two elements that have been chemically united (by which we mean combined in such a way as to form a substance different from either one), it is known as a *chemical compound. A chemical compound, therefore, is a substance composed of two or more chemical elements united in definite proportions.* One might naturally think that air is a chemical compound since it is composed of more than one kind of substance. But since the various elements and compounds found in the air are not chemically united, air is known as a *mixture.*

10. What is meant by oxidation. *Oxidation is the chemical union of oxygen with some other substance.* It may take place slowly as when carbon is made to glow in the air, or it may take place rapidly as when carbon burns in oxygen. But whenever oxidation takes place, (1) an oxid is formed (*e.g.* carbon dioxid is formed when carbon is oxidized), (2) a certain amount of heat is liberated, and (3) light is seen if the process is sufficiently rapid.

11. What is meant by matter. We find that the world about us is made up of countless objects that we can touch, see, taste, or smell. Each of these objects has length, breadth, and thickness; in other words, they all *occupy space.* Now, *any substance that occupies space is known as matter.* We have discussed carbon, oxygen, nitrogen, water, and carbon dioxid. All of these are forms of matter since they all occupy space. When we come to make a

further study of matter, we find that it has another characteristic besides that of occupying space. All matter, under conditions with which we are familiar, has *weight.*

IV. Soil and Water as Parts of Our Environment

12. What some of the characteristics of soil are. Anyone who has worked on a farm or in a garden knows that soil is made up of particles of varying degrees of coarseness. In ordinary soil the coarse solid masses are known as *gravel.* If these particles are much smaller, they are called *sand.* *Clay particles* are exceedingly minute. If we have a mixed sample containing all these components, they may be separated out in layers in the following way: Thoroughly mix a cupful of the soil to be tested in a tall jar of water and allow the mixture to stand until the water has become clear once more. We shall then find that the coarser parts, gravel, have settled on the bottom of the jar, the sand above them, and after some time the clay forms a layer above the others (Fig. 12). All these components of soil are purely of mineral origin. They are produced by the disintegration, or breaking down, of various kinds of rocks through the action of water, snow, and ice.

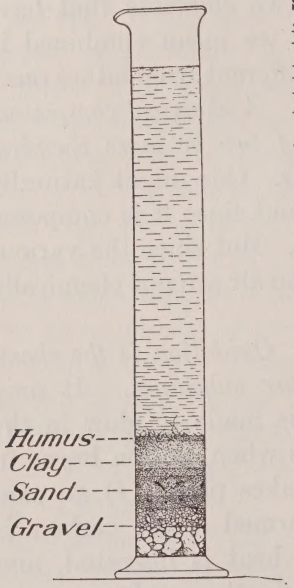

Fig. 12. — Experiment with soil

Note that the gravel settles first and the humus last.

Plants obtain most of the mineral foods they need from the clay and almost none from the sand, which is largely made up of grains of a very hard glassy substance known

as *quartz*. Sand, however, is a useful part of the soil, since it makes the ground loose, porous, and easy to cultivate. When leaves, straw, roots, or other plant materials decay or when animal wastes (manure) are added to the soil, they give to the earth the substances that are stored up in these compounds, much of which was originally taken from the soil. This decayed animal and vegetable matter is

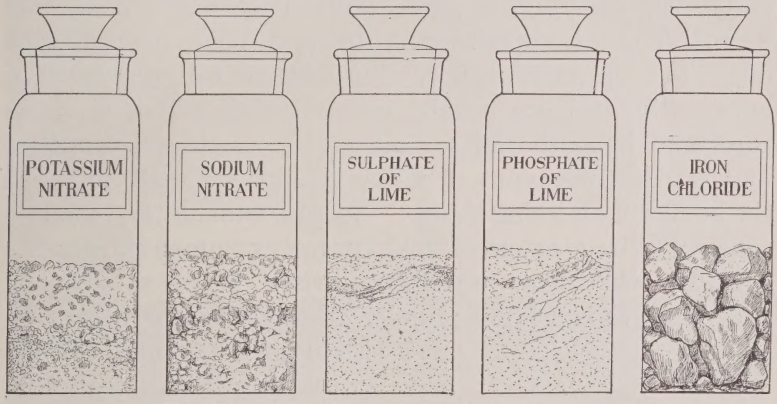

Fig. 13. — Chemical compounds found in soil

[**Do these compounds exist in the soil in pure form or in mixtures?**

known as *humus*. This is the dark-colored *top soil*, which is loose and easily penetrated by air, water, and the roots of plants (Fig. 207). *Loam* is a mixture of clay with sand or gravel and humus and is the most productive kind of soil.

Distributed in the finer particles of rich soil, especially near the surface, are important chemical compounds, which we shall find are used by growing plants. Among these necessary compounds are *sodium nitrate* (Chili saltpeter), *potassium nitrate* (saltpeter), *sulphate of lime* (gypsum), *phosphate of lime*, and *iron chloride* (Fig. 13).[1]

[1] The teacher should demonstrate the experiment described above, should show samples of various kinds of soil and the chemical compounds mentioned together with any others that are useful to plants. For the living components of the soil see **229.**

13. What the extent of our environment of water is. Geographers tell us that three quarters of the surface of our globe is covered by the waters of oceans, lakes, ponds, rivers, brooks, and the like. In the oceans the water is sometimes found to be more than five miles deep. Indeed it is estimated that, if the surface of the earth were level and if all the waters were to be evenly distributed over the globe, the covering of water would everywhere be a mile deep. The atmosphere absorbs and holds considerable quantities of water vapor. Particles of soil too, even if apparently dry, are usually covered with a film of moisture, and beneath the surface of the earth are countless underground reservoirs of water. Later we shall find that the bodies of all living things — plants, animals, and man — consist to a large extent of this extremely common substance.

14. In what forms water may exist. Water at ordinary temperatures is a liquid; under other conditions it may be an invisible gas or a solid. If one looks at a rapidly boiling teakettle, an apparently empty space extending about half an inch from the mouth of the spout is seen (Fig. 14). That this space is really filled with invisible water vapor can be readily shown by placing a cold plate close to the nozzle. The plate immediately becomes wet. This is due to the fact that the water vapor has become condensed by the cold surface. When the temperature of water is reduced to 32° Fahrenheit (or 0° centigrade), the liquid solidifies and expands, forming solid ice, which is somewhat lighter in weight than a corresponding volume of water and floats at the surface (Fig. 15).

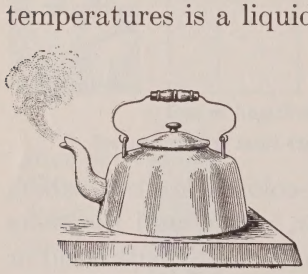

Fig. 14. — Boiling teakettle
Note the space at the mouth occupied by invisible water vapor.

15. What an examination of water reveals. *Visible particles.* Doubtless you have seen water that was not clear and transparent. If water of this sort is allowed to stand in a glass, a sediment settles to the bottom. Careful examination with a hand lens will show that this sediment consists of fine particles of soil. These particles have been

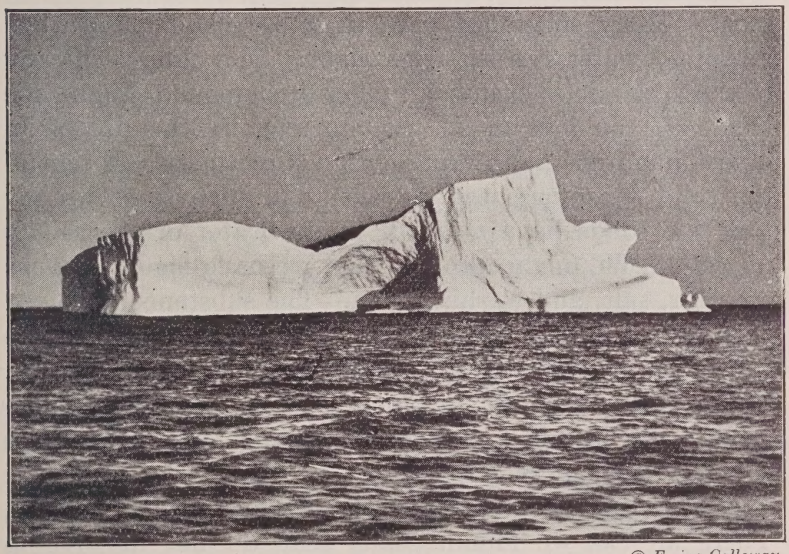

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Fig. 15. — A floating iceberg

The bulk of floating ice below the surface is about eight times as great as that above the surface of the water.

taken up by the water in passing over the bottoms and along the sides of the streams. If very many of these particles are present, one usually says that the water is muddy. After a heavy rain the waters of creeks and rivers are often so loaded with fine soil particles that one can not see the bottom of even shallow streams. All these particles, from whatever source they come, are solid, visible substances.

May water also contain substances that are invisible? To answer this question, suppose we try a simple experiment like the following: To a glass of water add a teaspoonful of sugar; to another, a teaspoonful of salt; to a third, a teaspoonful of sodium carbonate (washing soda) or of sodium nitrate. Stir the water in each glass for several minutes. Can the salt, the sugar, and the soda now be seen? Many substances like those we have tried, when added to water, vanish from sight. If a drop from any of these glasses is examined under a compound microscope (Fig. 48) (an instrument used to magnify the size of an object hundreds and even thousands of times), no sign of the solid substances can be seen. In such cases we say that the solids have *dissolved* in the water or are *soluble in water*. We might also say that we have made *solutions* of sugar, salt, and washing soda. The substance dissolved is known as a *solute;* that is, salt is a solute in water. The substance in which the salt dissolves is known as a *solvent.* Water is a solvent, for instance, of sugar and salt. Sometimes water is called the *universal solvent* since it dissolves so many substances.

How we can determine whether a substance really dissolves. There are, as we found, solids that do not dissolve in water or, like white of egg and starch paste, do not truly dissolve or break up into molecules. In these substances the molecules are held to each other in large enough masses so that their presence may be revealed in one way or another. In case the particles are not too small, they may be seen with the naked eye or with the compound microscope. If, however, the substance has been broken up into such an extremely fine condition that the ordinary microscope does not reveal these particles, they may be seen with a microscope known as the *ultramicroscope.*

If you have ever been in a darkened room into which a beam of sunlight was streaming, you will perhaps remember the unsuspected myriads of dust particles that you saw dancing in the beam of light. The ultramicroscope reveals particles in a similar way. The intensely concentrated rays of an electric arc lamp are made to pass through the liquid in the completely darkened field of a compound microscope. In a true solution nothing is revealed and no light is seen by the ultramicroscope. In the case of liquid containing white of egg, gelatin, or starch paste, the beam of light will be shown by the tiny particles that reflect the light, just as the dust particles reveal the light that enters a darkened room. That is, the particles reflect the light, revealing the light and themselves (Fig. 259).

In some instances a given amount of water will dissolve so little of a given solid that we say this solid is practically *insoluble* in water. Phosphate of lime, a valuable mineral matter found in milk, is such a solid. If now we put a teaspoonful of phosphate of lime in a glass of water and stir the mixture for several minutes and then allow the solid particles to settle, we are unable to find that a bit of this solid has dissolved. The amount of a solid that will dissolve in a given amount of water varies greatly — depending on the kind of solid that is used. Some solids, like common salt, are very soluble in water, while others, like phosphate of lime and sulphate of lime, are nearly insoluble.

The waters of brooks, creeks, and rivers in passing over and through soil dissolve smaller or larger amounts of the mineral matter, depending on the solubility of the minerals present. If the water has dissolved much mineral matter, it is said to be *hard water*. If it contains little or no mineral matter, it is said to be *soft water*. Rain water is very soft

since there can be no minerals dissolved in it. It may contain solid particles, such as soot and dust from the air. Except for the particles caught in the air, rain water contains nothing but water unless we include the small amount of air that may be dissolved in it.

Sea water contains a larger percentage of mineral matter than any other natural water. This is due to the fact that it has all the accumulations of the centuries brought down to it by the rivers. Common salt is the most abundant of the dissolved minerals in sea water. The waters of the Dead Sea and of Great Salt Lake contain so much mineral matter in solution that one can not sink in them on account of their great density.

Sea water furnishes a source from which may be obtained the salt that we use in seasoning our foods. The salt obtained in a crude form from salt mines is thought to have been left there by the evaporation of water of ancient seas.[1]

V. Living Things as a Part of Our Environment

16. The number and variety of living things in our environment. Plants and animals form an important part of our environment. Yet how few have any conception of the myriad forms of living things that are in the soil, on the surface of the earth, in the water, and in the air! Fishes, birds, domestic and many wild animals, trees, and ordinary plants of the field and garden are familiar to most of us. But how many people have any idea that the known kinds of insects number hundreds of thousands and that even a brief description of the various kinds of grasses fills a large-sized volume? More than this, the microscope has revealed

[1] It is suggested that the teacher evaporate some sea water or some of the water in which was dissolved the salt or sugar, to show that these substances have not been changed by being dissolved. Some of the pupils should taste the solid substances to see that they are unchanged in taste.

a world of living forms wholly invisible to the naked eye, forms which were absolutely unknown to those who lived less than a century ago.

Fig. 16. — Redwood trees of California

These giant sequoias are the largest and oldest living things on earth.

Our environment then includes all forms of plant life from microscopic germs in the air, earth, and water (Fig. 172) to gigantic redwood trees of California that tower to a height of three hundred feet (Fig. 16); from invisible living

animals that swarm in a drop of stagnant water to huge whales (Fig. 17).

17. In what ways living things may affect human welfare. We are absolutely dependent upon plants and animals for our food supply since everything we eat comes from

Courtesy American Museum of Natural History

Fig. 17. — Whale on the beach, Amagansett, L. I.

From such whales oil for illumination was secured before the discovery of petroleum.

living things. Materials for our clothing too come wholly from plant fibers like cotton and linen or from the skins or hair of animals. Wood and plant fibers are widely used in the construction of various kinds of shelter, and among savage races bark and skins still serve for this purpose. All our fuels too are derived from wood or from coal or from mineral oils, which were once vegetable or animal products.

On the other hand, certain plants and animals are poisonous; others, particularly insects, cause great damage to crops. Some animals carry disease germs, which we now know to be microscopic forms of life.

EXERCISE 6

A survey of the relations of living things to human welfare. Home work.

1. Make a list of materials, derived from plants and animals, used for shelter, and state the kind of plant or animal used in each case.
2. Make a list of materials, derived from plants and animals, used for clothing, stating the source of each as above.
3. Make a list of food materials derived from plants and animals, and state the kind of plant or animal that supplies the food in each case.
4. Make a list of plants and animals that are injurious to man, and state in what way each is injurious.

SUMMARY

Our *environment* in the limited sense includes all the lifeless and living things that surround us. In the larger sense our environment extends to the sun, moon, and stars and includes everything that either directly or indirectly affects human beings.

Each of us is responsible to a considerable extent for the kind of environment in which he lives; each of us should make his environment as healthful and attractive as possible.

Air is the most immediate part of our environment. It is a form of matter since it occupies space. It also exerts a pressure of about fifteen pounds to the square inch at sea level. About one fifth of air is *oxygen*, which causes things to burn; the other four fifths is almost wholly *nitrogen*, which neither burns nor causes other things to burn. Air also contains *carbon dioxid* and *water vapor*.

A chemical element is the simplest form of matter which may enter into combination with other substances. A *chemical compound* is a form of matter composed of two or more elements chemically united in definite proportions. *Oxidation* is the chemical union of oxygen with some other substance. A *mixture* is composed of elements or compounds or both, which are not chemically united. *Matter* is any substance that occupies space.

Soil is a mixture of chemical compounds of varying degrees of coarseness. It may be composed of clay, sand, and gravel, formed by the disintegration of rocks, and humus, produced by the decaying of bodies of plants and animals, the combination forming loam.

Water occupies three fourths of the surface of the earth. It is also found in the soil, beneath the surface of the earth, and in the air. Whether this substance is in the form of a solid, a liquid, or a gas depends on the temperature. Water may contain visible particles and also substances which have dissolved in it. Water is then spoken of as a *solvent*, and the dissolved substances as *solutes*.

Living plants and animals form a most important part of our environment. They vary in size from microscopic organisms to the giant redwoods of California or the whales of the sea. These living things may be of great value to man by furnishing food, medicines, shelter, and clothing, or they may be injurious by causing damage to crops or by producing diseases in man and other living things.

REVIEW QUESTIONS

1. Define and illustrate the term "environment."
2. Give specific statements to show the extent of our environment and our dependence upon various parts of the whole environment.
3. Show how a farmer is responsible for the character of his environment.

4. State several ways in which a home or a school environment may be improved.

5. Describe the experiments by which we proved that air occupies space and exerts pressure.

6. Give some idea of the extent of our environment of air. Discuss atmospheric pressure.

7. Define a chemical element. Name two chemical elements found in air. What have you learned as to the characteristics of each? What is the relative proportion of each, and how may this be determined?

8. What gas is required for the burning of carbon? How do you know that carbon burns more actively in pure oxygen than in air?

9. What is meant by burning, or oxidation? How can you tell when this process is going on?

10. Define a chemical compound. What compound is formed when carbon burns? How would you test for this substance? How could you prove that this substance is found in air? What are some of the sources of it in air?

11. How does a mixture differ from a compound? Name several mixtures with which you are familiar.

12. What is meant by matter? Give several examples of matter.

13. How do you know that water is found in air?

14. How do soils differ from one another?

15. Name several compounds found in soil that are necessary for plant life and growth.

16. Discuss the extent of our environment of water.

17. Name three forms in which water may exist. How can one form be changed into another?

18. Name at least two compounds that are commonly found in solution in water.

19. Define solvent, solute, and solution.

20. Give some idea of the number and variety of living things in our environment.

21. Show at least four ways in which living things are related to human welfare, giving several examples in each case.

PART II
ESSENTIAL FUNCTIONS OF LIVING THINGS

CHAPTER II

OF WHAT OUR FOODS ARE MADE

I. Classes of Food Substances

18. What the sources of food substances used by living things are. We have given some account of the changing world in which we live; we have studied some of the characteristics of air, water, and soil; and we have mentioned some of the living things found in our environment. We are now to consider more in detail one of the primary needs of all living things; namely, food.

Some of our foods come from plants (*e.g.* potatoes, beans, onions, grains (Fig. 18), cabbages, apples, and grapes); others are derived from animals (*e.g.* meats of various kinds (Fig. 19), milk, and eggs). Is each of these various foods composed of only one substance, or are all of them combinations of simpler food substances? It is relatively easy to answer this question by trying simple experiments like those that follow:

EXERCISE 7

Is flour composed of more than one kind of food substance? Home experiment.

Mix a tablespoonful of flour in water, tie it in a piece of cotton cloth or cheesecloth, and knead it for several minutes in a dish of water. Pour the water into a tumbler and allow it to stand for ten or fifteen minutes.

1. Describe what you have done.
2. Examine and describe the substance that settles in the glass of water.
3. How does the material in the cloth differ from the sediment in the glass?

4. What is your conclusion as to the composition of flour?

5. NOTE (to be copied). The substance that remains in the cloth is mainly composed of *wheat protein*, or *gluten*, and the sediment at the bottom of the tumbler is *wheat starch*.

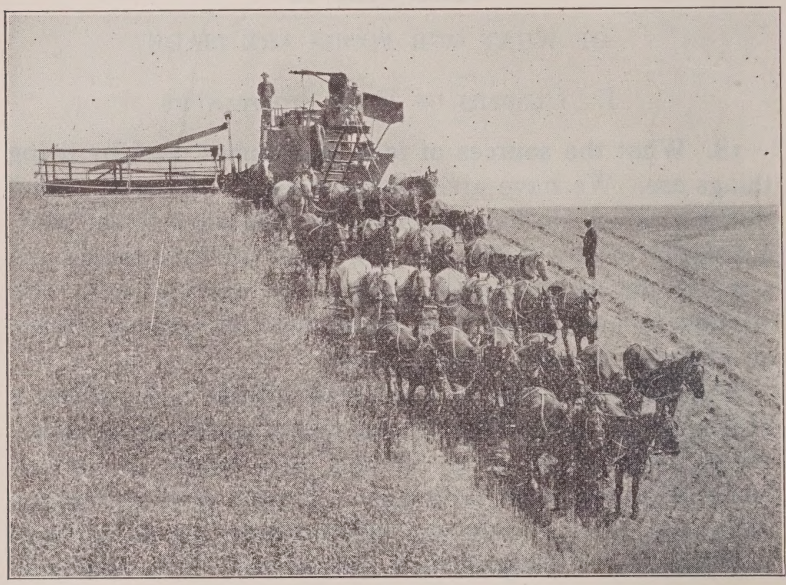

Fig. 18. — Harvesting in a Western wheat field

Wheat is our principal cereal food. Steam tractors like that shown in Fig. 29 and gasoline-driven tractors are now used to haul the harvesters. What is gained thereby?

EXERCISE 8

Is milk composed of more than one kind of food substance? Home experiment.

Examine a bottle of milk that has stood undisturbed for a time.

1. What is the difference between the color of the upper layer (cream) and the lower portion (skim milk)? Cream is largely composed of *fat*. Is cream heavier or lighter than skim milk? How do you know?

2. After pouring off the cream, add a spoonful of vinegar or of lemon juice to two or three spoonfuls of the skim milk, boil the mixture, and

strain through cheesecloth. How does the substance in the cloth differ both from the cream and from the skim milk?

3. Heat a spoonful of milk in a large, clean cooking spoon and hold over it an inverted clean, cold tumbler. What does the substance that you see collecting inside the tumbler seem to be?

4. Heat a quarter of a teaspoonful of the skim milk in a clean cooking spoon until the liquid evaporates, and burn the solid residue until the

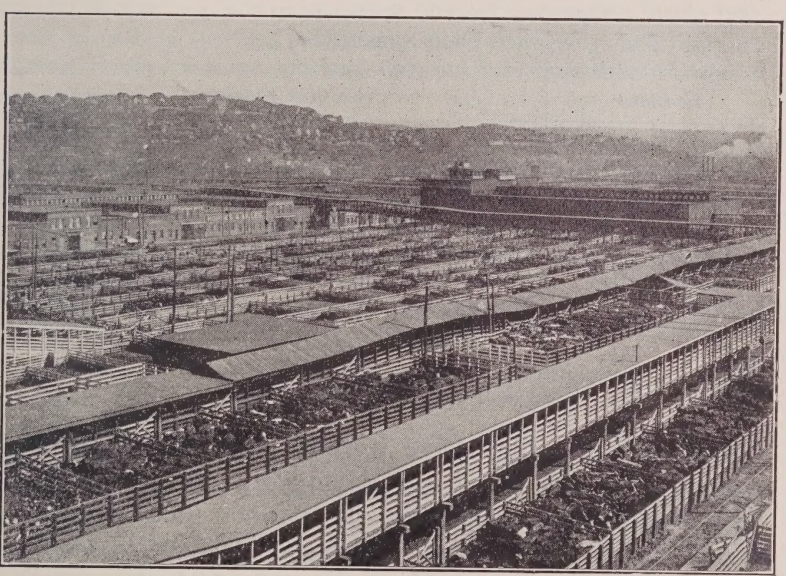

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Fig. 19. — Stockyards at Kansas City, Missouri

Why should the principal stockyards be located in the Middle West? Give as many reasons as you can.

black color disappears. What is the appearance of the substance that is left?

5. How many different kinds of substances have you found in milk?

6. Note (to be copied). Since butter is made from cream, it is evident that this part of milk is largely fat. The cheeselike substance that separates when milk sours is a *milk protein* known as *casein*. The solid substances left after the water evaporates and after the residue is burned are *mineral matter*.

19. What the classes of food substances are. In these experiments we separated some of the food substances of which our common foods are composed. All the food substances may be grouped into five classes, as indicated in the table below, two of them, starches and sugars, being classed together as carbohydrates.

FOOD SUBSTANCES

CLASSES	COMMON EXAMPLES
1. Carbohydrates	
a. Starches	Wheat starch, corn starch, potato starch
b. Sugars	Cane sugar, beet sugar, maple sugar
2. Fats	Cream of milk, butter, lard, olive oil
3. Proteins	Casein of milk, gluten of wheat, albumen of egg
4. Mineral matter	Common salt, ash of milk, phosphate of lime
5. Water	Drinking water, water in meat, fruits, and vegetables

II. TESTS FOR THE FOOD SUBSTANCES

20. How scientists have worked out methods of food analysis. In the above experiments simple methods have been employed in separating the various food substances found in common foods. We are soon to develop and use certain methods, or tests, by means of which the presence or absence of each of these substances can be indicated without this separation of the food substances. Now how were such tests derived? Most scientific discoveries are the result of years of investigation, and this is doubtless true of methods of analyzing and testing foods. In order to determine readily the presence or absence of a given food substance, it was necessary to find some definite means of distinguishing each of the food substances from all the others. That this is possible we shall now see.

EXERCISE 9

What is the effect of iodine on each of the classes of food substances? Laboratory demonstration or home work.

Arrange six test tubes, putting into each a small amount of one of the following food substances: starch (*e.g.* corn starch), sugar (*e.g.* granulated sugar), fat (*e.g.* lard or olive oil), protein (*e.g.* white of egg or casein), mineral matter (*e.g.* salt or phosphate of lime), and water. Add a little water to each of the food substances, shake thoroughly, and boil each mixture. Allow each to cool and then put into each tube a dozen or more drops of iodine solution.[1]

1. Give an account of the preparation of each of the tubes.
2. Describe your observations as to the color changes in each tube. In which tube is there a color produced different from that of iodine?
3. NOTE (to be copied). Iodine always has the same color effect on each of the classes of food substances that it had on their representatives in the above experiments.
4. What is your conclusion as to the effect of iodine on each of the classes of food substances named in 19 above?
5. State fully the steps you would take to determine whether starch is present or absent in any food (*e.g.* potatoes, corn meal, flour, milk).
6. Test six or more ordinary foods, some derived from plants and some from animals (*e.g.* milk, cereals, eggs, fruits, nuts, potatoes, parsnips). Record your results in a table like the following:

FOODS IN WHICH STARCH IS PRESENT	FOODS IN WHICH STARCH IS ABSENT

EXERCISE 10

What is the effect of grape sugar on Benedict's solution or Fehling's solution? Laboratory demonstration or home work.

Into a test tube put a small amount of grape sugar; add water and enough Benedict's[2] or Fehling's[2] solution to make the mixture slightly blue. Boil the contents of the tube.

[1] See Appendix II. [2] See Appendix II.

1. State the preparation of the experiment and give your observation and conclusion.

2. NOTE (to be copied). Benedict's and Fehling's solutions contain a blue substance (copper sulphate, or blue vitriol) in which copper is present. When boiled with grape sugar, this blue substance is changed, or *reduced*, to a simpler copper-colored compound, which is insoluble and finally settles in the bottom of the tube. None of the other classes of food substances affects these solutions as does grape sugar, nor do all of the sugars. The sugars which affect these chemical solutions in this way are known as *reducing sugars*.

3. Write out a method you would follow in testing an unknown food for a reducing sugar.

4. Test six or more ordinary foods (*e.g.* fruits, cereals, vegetables, and milk) and record your results in a table like the following:

FOODS CONTAINING A REDUCING SUGAR	FOODS NOT CONTAINING A REDUCING SUGAR

EXERCISE 11

How can the presence of fats in foods be shown? Home experiment.

Put a small amount of some fatty substance (*e.g.* lard, butter, or olive oil) on a piece of paper and hold the paper up to the light.

1. Describe the effect of the fat on the paper.

2. NOTE (to be copied). Fats and oils are the only food substances that affect paper in this way. The spots are translucent, that is, they allow light to pass through more readily than does the rest of the paper.

3. If the fat is combined with other food substances, as in milk or corn meal, it is necessary to heat the substance on paper in an oven or over the radiator in order to melt the fat and drive off the water. Write out a method you would follow in testing a given substance for fat or oil.

4. Sometimes the amount of fat in a food is so small that it is necessary to dissolve the fat by means of some substance like ether or benzine.

CAUTION: When using these substances, one should take care not to bring them near a flame.

To show that fat is dissolved by this method, grind up a few corn-grain embryos into a powder, put this powder into a test tube, and add a spoonful of ether or benzine. Cork the test tube, shake the mixture, and allow it to stand for ten or fifteen minutes. Now pour the liquid drop by drop on paper, allowing the ether or benzine to evaporate.

a. Describe the method employed.

b. What evidence have you that corn grains contain fat?

5. Test six or more ordinary foods (*e.g.* meats, nuts, milk, hard-boiled eggs, and flour). Record your results in a table like the following:

Foods in Which Fats Are Present	Foods in Which Fats Are Absent

EXERCISE 12

What is the effect of nitric acid on each of the classes of food substances? Laboratory demonstration.

Prepare six test tubes as in Exercise 9 above, but do not add water. Pour over each of the food substances diluted nitric acid, and bring to a boil.

1. How has the experiment been prepared?

2. Describe your observations as to color changes in each test tube.

3. Note (to be copied). Nitric acid always has the same color effect on each of the classes of food substances that it had on their representatives in the above experiments.

4. What is your conclusion as to the effect of nitric acid on each of the classes of food substances named in **19** above?

5. State fully how you would determine whether protein is present or absent in any food (*e.g.* potato, corn meal, flour, milk).

6. Test six or more ordinary foods (*e.g.* parsnips, meat, flour, onions, milk) and record your results in a table like the following:

Foods in Which Protein Is Present	Foods in Which Protein Is Absent

EXERCISE 13

What is the test for water? Home experiment.

1. Boil a little water in an old cooking spoon and place over it an inverted, dry, cool tumbler. What do you see on the inside of the glass?

2. NOTE (to be copied). Water is the only one of the five classes of food substances that will evaporate and condense in this way.

3. Test a number of foods by heating a small quantity of each in an old cooking spoon (without letting the food burn) and holding over the spoon in each case an inverted, dry, cool tumbler.

a. State fully how you would test an unknown food for water.

b. Record your results in a table like the following:

FOODS IN WHICH WATER IS PRESENT	FOODS IN WHICH WATER IS ABSENT

III. CHEMICAL COMPOSITION OF THE FOOD SUBSTANCES

21. Two kinds of food analyses. We have now learned, by separating them from one another, that most of our common foods are composed of several simpler food substances, and we have learned how to test for each of them except the mineral. We are now to determine whether each of these substances is composed of only one kind of matter or is a combination of still simpler substances.

EXERCISE 14

Is water a simple substance, or is it composed of two or more substances? Laboratory demonstration.

For this experiment an *electrolysis apparatus* similar to that shown in Fig. 20 is necessary. (If such an apparatus is not available, this experiment may be omitted, and the problem of the composition of water may be worked out in connection with Exercise 15.)

In order to induce an electric current to pass through water readily, add half a teaspoonful of sulphuric acid to a quart of water before pour-

ing it into the central funnel of the electrolysis apparatus. Open the two pet cocks at the top of the side tubes in order to fill each to the top with water. Attach the wires to a storage battery or to a light socket with a series of lights to cause resistance and allow the electric current to pass through the water.

1. Draw or describe the electrolysis apparatus, and describe the preparation of the experiment.

2. What evidence have you that water is being decomposed?

3. Are the substances forming at the top of the tubes liquids or gases? How do they resemble each other?

4. Are the bubbles coming off equally fast in both tubes? How do you know?

5. Determine in the following way whether the gases in the two tubes are the same or different:

a. Apply a burning splinter to the gas formed in larger volume while it escapes as you cautiously open the pet cock at the top of the tube. Does this gas burn? Repeat the experiment several times until you are sure.

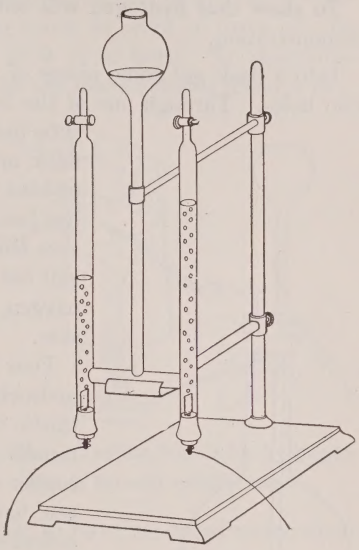


Fig. 20. — Electrolysis apparatus for decomposing water

What gas is bubbling up in each of the tubes? Give your reasons.

b. Hold a glowing splinter of wood or charcoal to the gas formed in smaller quantity in the other tube. Does it burn, or does it cause the splinter to burn more brightly? Repeat the experiment until you are sure of your answer.

c. What difference, therefore, do you find in the action of the two gases?

6. NOTE (to be copied). The gas formed in larger quantity is *hydrogen* (from the Greek, meaning *water maker*); the other gas is *oxygen*, already studied as one of the ingredients of air.

7. State your general conclusion as to the chemical composition of water.

EXERCISE 15

To show that hydrogen will burn and thus form water. Laboratory demonstration.

Into a flask put some pieces of zinc (Fig. 21). Insert a stopper with two holes. Through one of the holes pass the smaller end of a thistle tube until it nearly touches the bottom of the flask, and through the other run a short piece of bent glass tubing, the outer end of which has been drawn out to a fine diameter. *Make sure that all connections are tight* so that they will not leak, since a mixture of hydrogen and oxygen, when lighted, will cause an explosion.

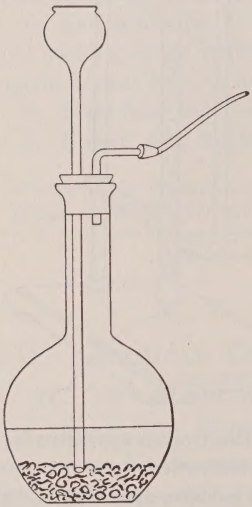


Fig. 21. — Apparatus for preparing hydrogen

Does the hydrogen come from the zinc or the hydrochloric acid?

Pour through the thistle tube enough diluted hydrochloric acid to cover the lower end of the thistle tube. (If hydrogen does not come off rapidly enough, put into the flask a bit of copper sulphate or a nail.) After the hydrogen has been given off for several minutes, collect some of it by inverting a test tube over the small end of the delivery tube. Now bring the mouth of the inverted tube near the flame of a Bunsen burner or an alcohol lamp. If an explosion occurs, collect and light another tube of hydrogen. When the hydrogen burns quietly at the mouth of the test tube, apply the burning gas to the end of the small delivery tube (Fig. 21).

1. Describe the experiment and state your observations.
2. Hold the mouth of an inverted, dry, cold glass tumbler or small jar over the burning hydrogen. What substance forms inside the glass?
3. What is the substance in air that causes the hydrogen to burn?
4. What does this experiment show as to the composition of water?
5. NOTE (to be copied). Hydrogen, like oxygen, is made of only one kind of matter and so is a chemical element. Water, on the other hand, is composed of hydrogen and oxygen chemically united in definite proportions. Hence, water is a chemical compound.

EXERCISE 16

Is hydrogen present in starches, sugars, and fats? Home experiment.

Warm some starch in an old cooking spoon in order to drive off any water that may be in it, but do not allow it to burn. To determine when the starch is free from water, hold the heated starch under a dry, cold tumbler, and, if no moisture collects on the tumbler, the starch contains no water. Now set the starch on fire, and hold a dry, cold tumbler over the flame (Fig. 22).

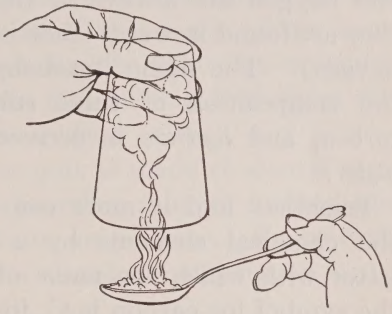


Fig. 22. — Testing starch for hydrogen
Why is the cold tumbler used?

1. Tell what you have done and state what is formed on the inside of the tumbler by the burning of the dry starch.

2. What is the only chemical element that could possibly form water by burning (*i.e.* by uniting with oxygen)?

3. What chemical element must have been present in the starch in order to have produced water when the dry starch is burned?

4. In the same way dry some sugar and some fat and determine whether hydrogen is present. State your results and your conclusions.

EXERCISE 17

Is carbon present in starches, sugars, fats, and proteins? Home experiment.

1. When wood, leaves, potatoes, bread, meat, eggs, or milk is partly burned, or scorched, what change in color occurs? What common name is given to the substance formed when wood, leaves, or foods are scorched?

2. Partially burn one of each of the starches, sugars, fats, and proteins. State your observations and your conclusions as to the presence or absence of carbon in each.

22. The chemical composition of food substances. *Water* is one of the simplest of the food substances in its composition since it consists of only two elements, hydrogen and

oxygen, united in the proportion of two parts of hydrogen to one part of oxygen.

The *carbohydrates* include the starches and the sugars. These are composed of the three elements: carbon, hydrogen, and oxygen. In starches and sugars the hydrogen and oxygen are always in the same proportion in which they are found in water (that is, twice as much hydrogen as oxygen). The name "carbohydrate," therefore, describes the composition of these substances, for *carbo* signifies *carbon*, and *hydrate* is derived from the Greek, meaning *water*.

Scientists find it more convenient to represent each of the chemical elements by a *symbol*, usually the capital letter with which the name of the element begins. Thus the symbol for carbon is C, for hydrogen H, for oxygen O, and for nitrogen N. In grape sugar there are six parts of carbon, twelve parts of hydrogen, and six parts of oxygen. Hence the *formula* for grape sugar is $C_6H_{12}O_6$. It should be borne in mind, however, that no carbohydrate is simply a combination of carbon with water; instead, all the elements are closely united to each other.

Fats too are composed of carbon, hydrogen, and oxygen but not in the same proportion as in carbohydrates. For this reason they are put in a separate class of food substances.

Proteins are by far the most complicated and varied in their composition of all the food substances. Not only do they contain carbon, hydrogen, oxygen, and nitrogen, but another element, sulphur (S), is usually present, and sometimes other elements as well.[1]

It is impossible to give any general statement as to the

[1] The following formula will give some idea of the extreme complexity of the composition of a protein that is found in the blood (as compared with the relatively simple composition of a carbohydrate): $C_{720}H_{1134}O_{248}N_{218}S_5$.

composition of the various kinds of *mineral matter* since no two of them are alike. Most of them, however, are white crystalline or powdery solids. Common salt (NaCl), for instance, or sodium chloride, as the chemists call it, is composed of two elements, sodium and chlorine. Sodium nitrate ($NaNO_3$) is made up of three elements — sodium, nitrogen, and oxygen. Whenever the name of the compound ends with *ate* or *ite*, we may be sure that oxygen is present. In calcium sulphate ($CaSO_4$) we find three elements, calcium, sulphur, and oxygen.

A food like flour, raisins, or milk is made of several compounds, such as sugar, fats, proteins, mineral matter, and water, which are not in definite proportions. Hence each, like air, is a *mixture* and not a chemical compound.

Analysis of Food Substances

Name	Test
Starches	Turn blue with iodine solution
Reducing sugars	Form a yellow or brick-red precipitate when boiled with Benedict's or Fehling's solution
Proteins	Turn yellow with nitric acid
Fats and oils	Leave a translucent spot on paper
Mineral matters	Remain as grayish ash after food is completely burned
Water	Forms in colorless drops on the inside of a cold tumbler when a food containing it is heated underneath the tumbler
	Chemical Composition
Water	Hydrogen (H), which burns; oxygen (O), which causes burning. Formula of water: H_2O
Starches, sugars, fats	Carbon (C), hydrogen (H), oxygen (O)
Proteins	C, H, O, nitrogen (N), and sulphur (S) usually, and sometimes other elements
Mineral matters	Many different elements, for example, salt, or sodium chloride (NaCl), and phosphate of lime ($Ca_3(PO_4)_2$)

Summary

Our *foods* are derived either from plants or from animals. These foods are mixtures of the several classes of food substances in varying proportions. *Wheat flour* is largely composed of starch and proteins with some mineral matter. *Milk* is made up principally of protein, fat, and sugar together with some mineral matter. All foods, unless dried, contain a considerable proportion of water. *Food substances* are always compounds.

REVIEW QUESTIONS

1. How would you prove that each of the following foods is made up of two or more food substances: flour, raisins, milk?
2. Name five groups of food substances and give examples of each.
3. How would you test an unknown food for each kind of food substance?
4. Name the chemical elements found in starches, sugars, fats, and proteins.
5. How did we prove that carbon and hydrogen are present in food substances?
6. Name the chemical elements found in water. In what two ways was this shown?
7. Name the chemical elements found in two kinds of mineral matter.

CHAPTER III

HOW PLANTS MANUFACTURE FOOD

23. What food substances exist ready-made, and what must be manufactured by plants. All our common foods, whether derived from plants or animals, contain both water and mineral matter. Since these two classes of compounds found in our foods are also found either in the air or in the soil, it is evident that both water and mineral matter exist ready-made for our use.

We have found that starches, sugars, fats, and proteins are food substances derived from plants or animals. Do these food substances likewise exist ready-made in the air, water, or soil, or must they be manufactured by living things? We can account for their presence in animals because animals feed upon plants or upon other animals that secure their foods from plants. Plants, therefore, must somehow make the starches, sugars, fats, and proteins used by animals, by man, and by plants themselves since no one has ever discovered a supply of these substances in soil, water, or air.

24. Whence the materials used by plants in making carbohydrates come. We have learned that plants are surrounded by soil, water, and air. Evidently a plant must obtain all the materials it uses from these sources. In other words, soil, water, and air must contain the substances that ultimately furnish all the elements needed by plants.

We have proved that carbohydrates, fats, and proteins are all compounds; that starches, sugars, and fats contain

only carbon, hydrogen, and oxygen; and that proteins have nitrogen in addition to these three elements, and usually sulphur and sometimes other elements as well. One might suppose that the plant could use the oxygen of the air in making carbohydrates and fats and both the oxygen and the nitrogen in making proteins. It has been demonstrated, however, that no living organism can manufacture food from chemical elements. Instead, simple compounds containing these elements must be available.

From what compound, then, in soil or air is derived the hydrogen, which is always present in carbohydrates? Thus far we have mentioned the following compounds as being present in air or soil:

Carbon dioxid (CO_2)	Sodium nitrate ($NaNO_3$)
Water (H_2O)	Potassium nitrate (KNO_3)
Calcium sulphate ($CaSO_4$)	Calcium phosphate ($Ca_3(PO_4)_2$)

Evidently water is the only one of these compounds that contains hydrogen, and this will help us to remember that the hydrogen for carbohydrate manufacture is all derived from this source. It is probable that the needed oxygen is also obtained from water, especially since in all the carbohydrates the hydrogen and the oxygen are always in the same proportion as in water (H_2O).

From what compound does a plant obtain its necessary supply of carbon? Going over the list of compounds in the preceding paragraph, we find that carbon is present in carbon dioxid only. Hence this compound, it would seem, must be the source of the needed carbon. But before we state anything further concerning this fact, we must discuss some of the essential conditions for food manufacture.

25. What the possible conditions may be that are necessary for carbohydrate manufacture. All of us know that

familiar plants have green leaves and that during a part of the twenty-four hours the leaves are exposed to sunlight. We also know that the temperature varies from season to season. We shall now proceed to determine by experiments whether sunlight and green coloring matter (*chlorophyll*[1]) are essential for carbohydrate manufacture.

EXERCISE 18

Is sunlight essential for starch manufacture? Laboratory demonstration.

Select a vigorous green plant (*e.g.* geranium or hydrangea). Cover some of the leaves loosely with black carbon paper in such a way as to exclude all sunlight but to permit free circulation of air. Put the plant in direct sunlight in a warm room, or out of doors if the weather is favorable, and leave it for at least forty-eight hours. Now remove a leaf that has been exposed to sunlight and also one that has been covered. Break off the stem of the leaf that was deprived of sunlight so as to distinguish it from the one exposed to sunlight.

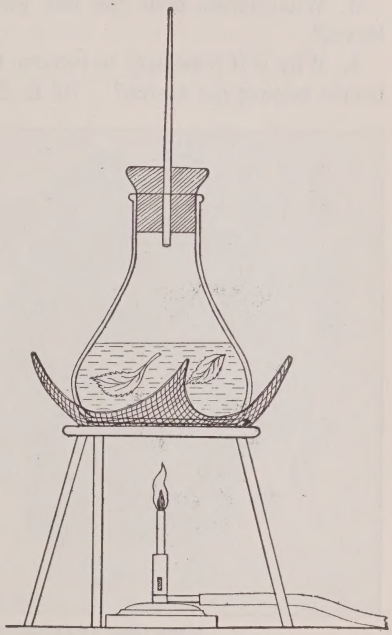


Fig. 23. — Apparatus for removing chlorophyll

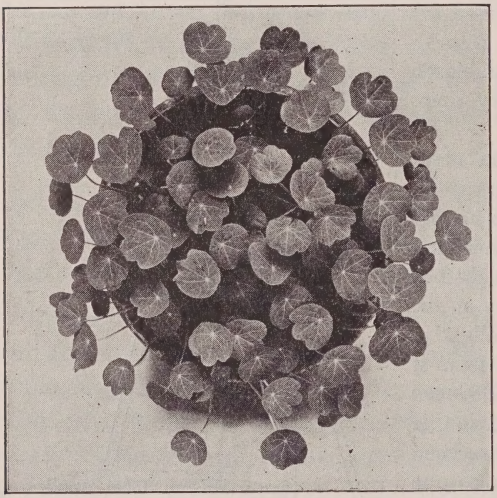
What liquid is used in this experiment, and why?

Boil the two leaves in water for a few moments in an agate or other available dish so as to soften the leaves. Remove the leaves from the water and put them into a flask with enough alcohol to cover them (Fig. 23). Boil the alcohol over a piece of wire gauze or asbestos until all the green matter has been removed from the leaves. Rinse the leaves in water and test them in a saucer or Petri dish for starch. (Care must

[1] Chlorophyll is derived from the Greek, meaning *light-green leaf*.

be taken of course to prevent the alcohol fumes from catching fire. It might be well to insert in the mouth of the flask a stopper, through which passes a glass tube at least six inches long.)

1. Describe the experiment as performed.
2. Why are some of the leaves covered with carbon paper?
3. What effect does the hot water and the alcohol have on both leaves?
4. Why is it necessary to remove the coloring matter from both leaves before testing for starch? (If in doubt, add some iodine solution to green leaves that have been boiled in water only.)
5. Give your observations after the leaves are tested for starch.
6. State your conclusion in each case.
7. NOTE (to be copied). Many experiments have been tried by scientists on geraniums and other plants under the same conditions with similar results.
8. State whether or not a plant must be exposed to sunlight in order to manufacture starch.



From Gager's Fundamentals of Botany

Fig. 24. — Leaf exposure to light

Note that the leaves are so arranged as not to shade one another.

EXERCISE 19

Is chlorophyll in plants necessary for starch manufacture? Laboratory demonstration.

Secure a plant having leaves that are partly green with chlorophyll and partly colorless (*e.g.* silver-leaf geranium or coleus (Fig. 25). Expose the plant to direct sunlight in a warm room or out of doors for several hours. Remove a leaf and test it as directed in Exercise 18.

1. Describe the way the experiment is performed.

2. What is your observation, and what is your conclusion as to the presence of starch in the green and in the colorless portions?

3. NOTE (to be copied). Similar results have been obtained with leaves of other kinds of plants that have both green and colorless parts.

4. State whether chlorophyll is or is not necessary in plants for starch manufacture.

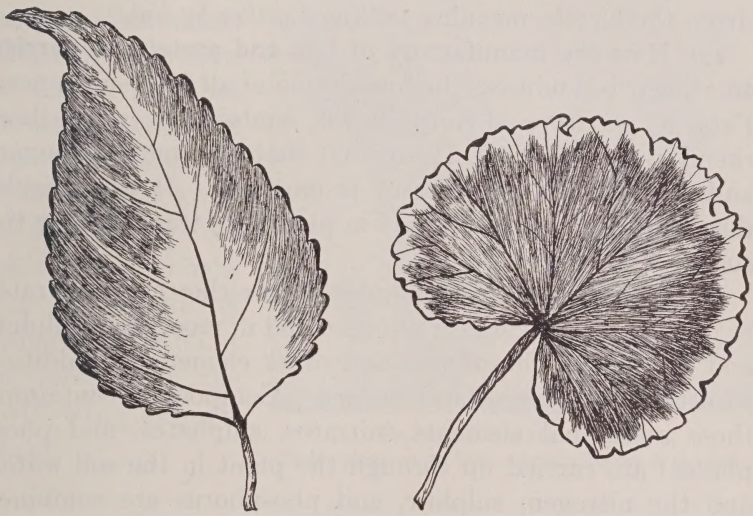


Fig. 25. — Leaves with green and non-green portions
Coleus leaf at the left; geranium leaf at the right.

26. How the manufacture of carbohydrates is carried on in green plants. The necessary compounds for carbohydrate manufacture (*i.e.* carbon dioxid and water) must be supplied to the leaves or other green parts of a plant. Then sunlight must act upon the chlorophyll. Through the action of the sunlight the chlorophyll combines the chemical elements (carbon, hydrogen, and oxygen) found in carbon dioxid and water, thus forming a carbohydrate (Fig. 37). Sugar is made before starch, and the sugar is changed to starch only when more sugar is formed than the

plant needs for its immediate use. It is easier to prove the presence of starch than of sugar in leaves, and for this reason we have used the starch test to show that carbohydrate manufacture is going on. To this process of carbohydrate manufacture is given the name *photosynthesis* (from the Greek, meaning *putting together by light*).

27. How the manufacture of fats and proteins is carried on. Sugar is doubtless the foundation of all food substances. Fats, as we have already shown, contain the same three chemical elements (C, H, and O) that are found in sugars and starches but in different proportions. It is probable, therefore, that fats are made in plants by transforming the sugar.

Proteins are far more complex than either carbohydrates or fats since they contain nitrogen and in most cases sulphur and sometimes phosphorus and other elements in addition to carbon, hydrogen, and oxygen. Compounds containing these additional elements (nitrates, sulphates, and phosphates) are carried up through the plant in the soil water, and the nitrogen, sulphur, and phosphorus are combined with the sugar already formed (Fig. 44). In the manufacture of proteins neither sunlight nor chlorophyll is essential; hence these food substances may be formed in any part of a plant and at any time. A moderate degree of warmth, however, is essential for the making of proteins and for carbohydrate and fat production as well.

28. Why food manufacture in green plants is important. This process of food manufacture in plants that contain chlorophyll is the foundation of all the food supply of the world since all plant foods are dependent upon the formation of carbohydrates. Animals are unable to make any of the food substances out of carbon dioxid, water, and mineral matter as do green plants. They can only trans-

form in their own bodies the carbohydrates, fats, and proteins secured from plants or from other animals.

We have said that a plant obtains its carbon from the carbon dioxid and its hydrogen and oxygen from water. What then becomes of the oxygen that forms a part of the carbon dioxid? That a gas is given off from green plants in sunlight can be shown by using a water plant as directed in the following experiment.

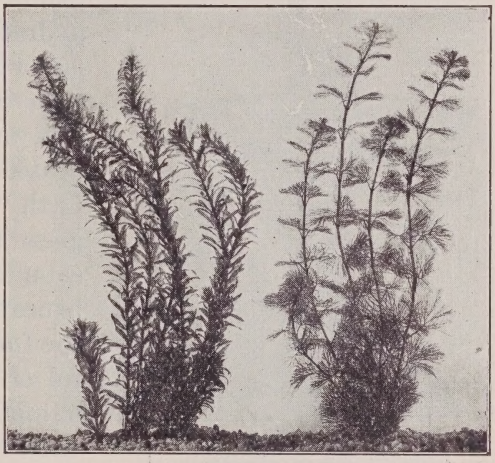


Fig. 26. — Aquarium plants
Elodea plants at the left; cabomba leaves at the right.

EXERCISE 20

Do green plants give off a gas in sunlight, and not in darkness? Laboratory demonstration.

Into each of two tall glass cylinders put some fresh water that has been poured from one jar into the other several times, in order to secure a plentiful supply of carbon dioxid, and several sprays of Elodea (Fig. 26), milfoil, or other plant that grows beneath the water, fastening the plants at the bottom of the jars by means of a weight if necessary. Put one of the cylinders in direct sunlight and cover the other with a lightproof box, keeping the temperature the same in both cases.

1. Describe the preparation of the experiment.

2. Examine the jar that has been in sunlight; then quickly raise the box and look at the other jar. State your observations in both cases.

3. What is your conclusion from the experiment with the plant that you have used?

29. What gas green plants give off in sunlight. The following method may be used to determine the kind of gas given off when green plants manufacture carbohydrates.[1] A large glass jar or an aquarium is filled with water that has been well mixed with air by repeated pouring back and forth. In the jar a large glass funnel is completely submerged (Fig. 27), and beneath the larger end of the funnel is placed a handful of water plant (Elodea or milfoil). Over the smaller end of the funnel is inverted a test tube filled with water. (Be sure that the mouth of the test tube is under water.) When the apparatus is put in strong sunlight, bubbles of gas rise from the water plant through the funnel and gradually force the water out of the test tube. After the test tube is filled with the gas, the funnel is removed from

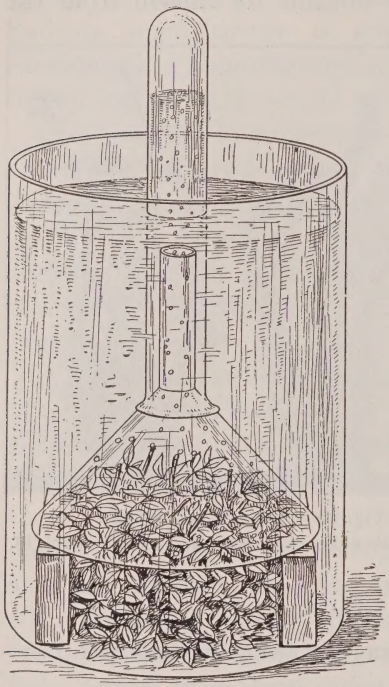


Fig. 27. — Aquarium plants in sunlight
What gas is bubbling up through the water?

[1] This experiment is extremely difficult to perform successfully since bubbles of air from the outside of the plant are sure to mingle with the oxygen that comes from the inside of the plant. It is also difficult to keep the plant in the direct sunlight long enough to get sufficient oxygen to make the test. Again, if the preparation is left overnight, the plant gives off carbon dioxid (instead of oxygen), which mingles with the gases in the test tube and so neutralizes the effect of the oxygen. The student should know, however, that extremely delicate experiments have been performed which show that the gas given off from green plants in sunlight is oxygen.

the test tube under the water, and the mouth of the tube is covered with the thumb. On removing the test tube and thrusting into it a glowing piece of carbon, we find that the carbon either bursts into a flame or glows more brightly than in air. This proves that the gas given off in the presence of sunlight is oxygen since there is more oxygen present than in ordinary air. It has been found that the oxygen obtained in this way corresponds exactly to the amount supplied by the carbon dioxid.

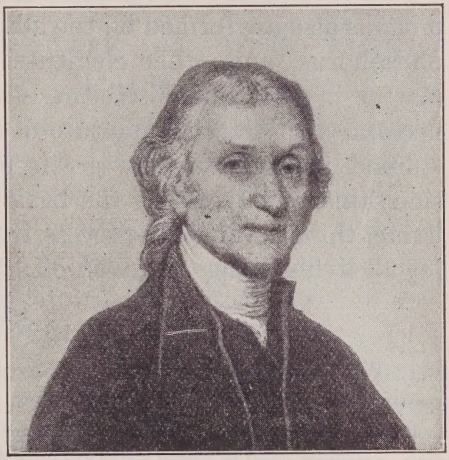


Fig. 28. — "The Father of Modern Chemistry" (1733-1804)

Joseph Priestley of Pennsylvania who discovered oxygen and made pioneer studies of the function of chlorophyll.

Summary

Of the five classes of food substances, water and mineral matter exist ready-made in soil or air. Carbohydrates, fats, and proteins are not ready-made; instead *these compounds are manufactured by green plants.*

Sugar is the first food substance made. From water the green plants secure the necessary hydrogen and oxygen for sugar manufacture; carbon dioxid furnishes the carbon that is required.

In order to carry on carbohydrate manufacture (*photosynthesis*) *sunlight, green material* (*chlorophyll*), and a *favorable temperature* are necessary. Sunlight causes chlorophyll

to recombine the carbon, hydrogen, and oxygen that exist in carbon dioxid and water to form *carbohydrates*.

Fats are made by transforming sugar. From sugar *proteins* also are formed by the addition of nitrogen, sulphur, phosphorus, and other elements supplied by the mineral matter in soil water. Neither sunlight nor chlorophyll is necessary for the manufacture of fats and proteins.

Food manufacture by green plants is most important since this process forms the basis of all the food supply of living things. In this process oxygen, which is necessary for all living things, is given off.

REVIEW QUESTIONS

1. Which of the food substances does a plant make first? What two compounds are necessary for this process, and what is the source of each?
2. State what compounds a plant uses to make starch, fat, and protein. How is each of these substances obtained?
3. Why is it unnecessary for a plant to manufacture water and mineral matter?
4. What is the meaning of the term "photosynthesis"?
5. State two conditions that must be present if a plant is to carry on photosynthesis.
6. Describe the experiments by which we showed that each of these conditions is essential.
7. Which of the conditions referred to above is not necessary for the manufacture of fats and proteins?
8. How do you know that a gas is given off during the process of photosynthesis, and what is this gas?
9. Give two reasons why the process of food manufacture in green plants is important to animals and man and one reason why this process is important to plants.

CHAPTER IV

HOW LIVING THINGS ARE ABLE TO DO WORK

30. Some examples and a definition of work. If you were asked to give some examples of work, you might mention activities like the following: shoveling coal or snow, pushing a lawn mower or a carpet sweeper, or riding a bicycle uphill. In each of these activities a body of matter is set in motion. It must be evident too that muscular effort is necessary to set the lawn mower in motion and to keep it in motion. These lifeless objects seemingly *resist* our efforts to move them. *Whenever resistance is overcome, work is being done.* Hence in all the activities named above work will be done since resistance is being overcome.

Likewise, if we attempt to stop a body that is in motion, it resists our efforts. Thus, if an automobile were started, we would find that, if we attempt to stop it, we must make an effort since the car seemingly resists being stopped. So work may be done by stopping the motion of a body.

We may now ask whether work is carried on by any agency other than man. If trains, trolley cars, or elevators are to be set in motion and kept in motion, resistance on the part of these bodies of matter must be overcome, and therefore work must be done. Now let us see what it is that does the work in these cases.

31. What energy is. The ability to do work or to overcome the resistance of a body so as either to cause motion or to stop motion is known as *energy*. In briefer form *energy is the ability to do work*. We may say, therefore, that

it must be some form of energy that does the work or that overcomes the resistance in all the cases mentioned above.

32. What some of the forms of energy in our environment are, and how they may be recognized. The move-

© *Brown Bros.*

Fig. 29. — A tractor pulling fourteen bottoms

What evidence have you that the tractor is doing work? Why is the steam tractor being displaced by the gasoline tractor?

ments of bodies of matter, either large or small, as in the examples named in **30**, furnish the clearest evidence that energy has been or is being expended. An electric current causes a fan to revolve or an elevator to rise or a trolley car to go. Therefore the *electric current* is a form of energy, since in overcoming resistance it is causing motion and so is doing work. *Heat* is also a form of energy, for it causes the mercury to rise in a thermometer (Fig. 34) or the cover

of a teakettle to bob up and down or the locomotive engine to go when the water is changed to steam.

The *radiometer* (Fig. 30) is an instrument which shows that light also is a kind of energy. This instrument con-

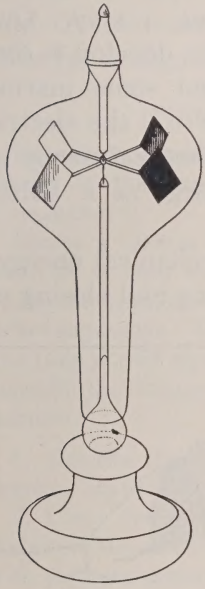
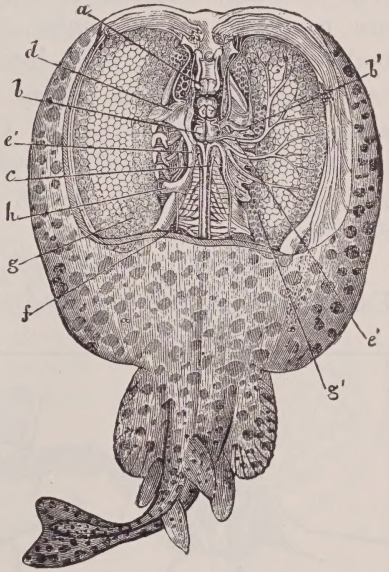


Fig. 30. — Radiometer

This instrument was devised by Sir William Crookes (1832–1919).



From Packard's Zoology

Fig. 31. — The torpedo fish

The organ on either side that looks like honeycomb (*g*, *g'*) releases the electric energy.

sists of a small glass bulb within which are four thin metal blades mounted on a needle point so as to revolve like a windmill. One side of each metal plate is blackened. When this instrument is exposed to direct sunlight or electric light, the blades revolve rapidly. As the radiometer is withdrawn from the source of light, the speed of the revolution decreases, and in the dark motion ceases altogether.

Since, then, light causes motion or does work, it is a form of energy.

33. What kinds of energy are developed in living things. All the activities of our own bodies in which we use muscles (*e.g.* walking, running, lifting objects, playing the piano) are examples of *muscular*, or *mechanical, energy*. Our bodies and those of most living things also develop a certain amount of *heat energy*. Fireflies and some marine animals give off *light energy*. Certain fishes (*e.g.* the electric eel and the torpedo fish) develop enough *electrical energy* to give a distinct shock to an animal as large as a horse. See Fig. 31.

In plants too there are evidences of mechanical energy. Examples that may be cited are the opening and closing of

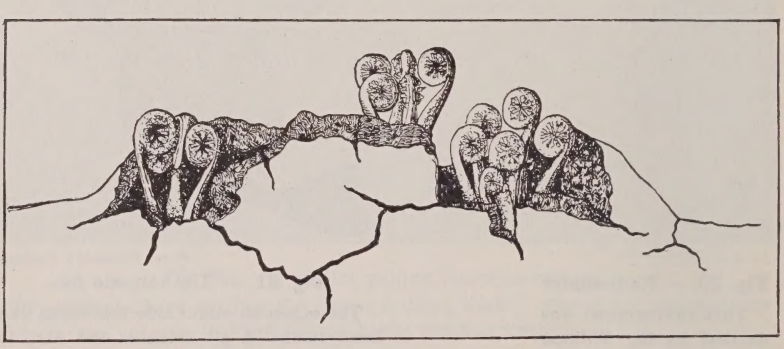


Fig. 32. — Exhibition of energy in plants
These fern plants in growing have broken their way through concrete. (After Stone.)

leaf buds and flower buds, the movement of leaves toward the light (Fig. 35), the pushing of roots through the soil. Indeed we may have noticed that heavy flagstones of a sidewalk have been lifted by growing plants (Fig. 32) or that rocks have been split apart by the growth of tree trunks.

In carbohydrate manufacture also the light energy is used by the chlorophyll bodies to separate the compounds carbon dioxid (CO_2) and water (H_2O) into their elements and then to recombine these elements (C, H, and O) to form sugar, which may then be changed to starch or fat.

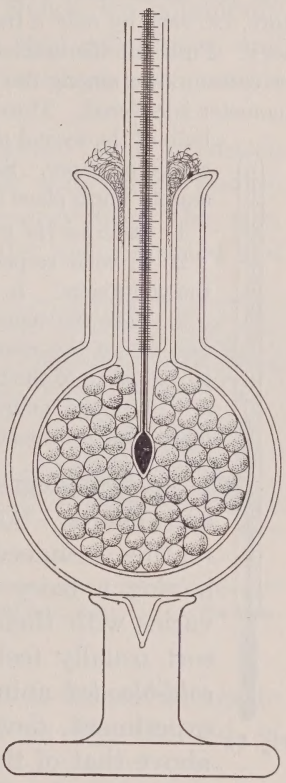


Fig. 33. — A Dewar flask
This was invented by Sir James Dewar (1842-1923). Note that one flask is inside the other, with a vacuum between them. A thermos bottle is similar in construction.

EXERCISE 21

How can we measure the degree of heat energy in the human body? Laboratory demonstration.

Secure a clinical thermometer (Fig. 34), such as is used by a doctor or a nurse. Shake the thermometer to bring the mercury as low as possible. Wash the bulb in alcohol, and rinse in cold water. Now place the bulb beneath the tongue of a pupil for three minutes.

1. Describe the experiment and state the degree of heat registered on the thermometer.
2. Clean and shake the thermometer as described above and repeat the experiment with several students. What is the average degree of heat developed in the bodies of the students tested?

EXERCISE 22

How can we show that heat energy is developed in growing seedlings? Laboratory demonstration.

Secure two wooden crayon boxes with covers or, better, two unsilvered Dewar flasks (Fig. 33) or thermos bottles if they are available.[1] Put some wet cotton batting or pieces of wet blotting paper in the

[1] Care should be taken to remove the sprouting grains from the Dewar flasks before the young plants become intertwined.

bottom of each. Fill one of the containers two thirds full of sprouting peas, oats, or barley and slide in the covers or close the flasks with cotton. Get two thermometers that register approximately the same temperature, *i.e.* vary by only a fraction of one degree in the air of the laboratory. Push one thermometer through a hole in the middle of the cover or cotton down among the sprouting seeds, so that the bulb of the thermometer is covered. Through a hole in the cover of the other push the bulb of the second thermometer until it is in contact with the wet cotton or paper. Set the boxes or flasks side by side in a moderately warm place for several hours.

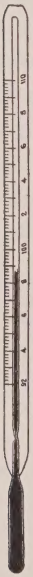


Fig. 34

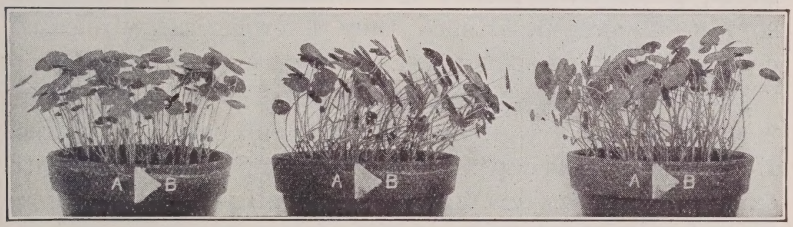
1. Describe the preparation of the experiment.
2. In what respects are the conditions the same in both of the containers? In what one respect do they differ?
3. Take the temperature readings of the thermometers in each and record the results. What difference do you notice in the temperature of the two?
4. What is your conclusion from the experiment as to the development of heat energy in the seedlings studied?

34. The degrees of heat energy released in animals and plants. Some animals, like fishes, frogs, and reptiles — indeed all animals except birds and animals having a hairy covering — have a temperature that varies with their surroundings. Since animals of this sort usually feel cold to the touch, they are called *cold-blooded* animals. Plants too, as we proved by experiment, develop a degree of heat only slightly above that of their surroundings.

Man, on the other hand, and other higher animals, like dogs, horses, and elephants, have a nearly *constant temperature*, which may be higher or lower than their environment. This temperature for an adult human being in health is approximately 98.6 degrees (Fig. 34) whether a man is traveling in the Arctic regions or in the tropics. Birds usually have a higher temperature, reaching ten degrees or more above that of man.

35. Why it is that food substances are a source of energy. When we burned sugar, starch, fat, or protein, both heat and light energy became evident. Hence we commonly say that energy is stored up in these food substances, and we, therefore, call them *fuel foods*. Now how is it possible to get energy from our foods?

A green plant is unable to manufacture sugar or starch without the action of light upon the chlorophyll bodies. Through the action of the radiant energy from the sun, the elements in carbon dioxid and water are combined and



From Gager's Fundamentals of Botany

Fig. 35. — Exhibition of energy in plants

The nasturtium seedlings are shown after three exposures to light for forty-eight hours: at the left, light from all sides; in the center, light from right only; at the right, light from left only.

rearranged to form sugar. Now what is the advantage to living things of this process carried on by the aid of sunlight?

We all know that neither carbon dioxid nor water will burn, that is, unite with oxygen. The reason for this is that the carbon in carbon dioxid has already united with all the oxygen it can. Likewise the hydrogen in burning will only unite with just enough oxygen to form water. On the other hand, whenever the carbohydrates are formed, a certain amount of oxygen is given off. So, when carbohydrates are burned, or oxidized, they can unite with the

same amount of oxygen as was given off when the carbohydrate was formed.

It is during this process of union of the chemical elements when carbohydrates are burned that energy becomes apparent. Hence the sun's energy is used in forming compounds (sugar and starch) that can be oxidized, or burned, from compounds (carbon dioxid and water) that can not be burned. Sugar is essential for the making of starch, fats, and proteins. Since each of these food substances likewise can be burned, it is evident that they too, like sugar, possess the ability to combine with an additional supply of oxygen. Hence they likewise can "release" energy when they are burned.

36. Why it is that fuels are a source of energy. When wood, coal, oil, or gas is burned, heat and light are set free. Hence these fuels must have the ability to combine with oxygen and release energy. Wood is made by plants from sugar just as much as are fats and proteins. So too coal, petroleum, and gas are products formed from the plants (Fig. 36) or from animals that lived in ages gone by and were all originally derived from the sugar made by plants through the help of the sun's rays. Hence we see that the sun is the ultimate source of all our energy. Many theories have been advanced to explain the source and release of energy in the sun, which is about 93,000,000 of miles away, but such explanations do not concern us here.

37. How energy is released from foods and from fuels. Our experiments in burning foods and common experience in burning fuels show us that air is necessary for this process. The carbon of the food or fuel combines with the oxygen of the air, forming carbon dioxid, and heat and light are released. In our experiment with pure oxygen we found that this gas caused the rapid burning of the hot

carbon; we proved that carbon dioxid was formed and that, when the oxygen was used up, the light went out. Hence oxygen causes the burning and the consequent release of energy.

From Sargent's Plants and Their Uses

Fig. 36. — Giant tree ferns

Plants like these formed the coal strata ages ago.

EXERCISE 23

Do seeds need air in order to release energy for growth? Laboratory demonstration.

Secure two wide-mouthed bottles and place in the bottom of each a wet sponge or some wet blotting paper. Pour into each bottle just enough water to cover the sponge or paper. Fill both bottles with pea seeds (or other seeds) that have been soaked in water twenty-four hours. Insert a tight-fitting cork into the mouth of one bottle to exclude the air. Leave the other bottle open to the air and add enough water from day to day to make up for the loss by evaporation. Put both bottles in a moderately warm place.

1. Describe this experiment, showing in what respects conditions are the same for both groups of seeds.
2. In what respects do the conditions differ?
3. At the end of several days examine both bottles of seeds and state your observations concerning the amount of growth of the seeds in each bottle.
4. State clearly your conclusions as to the necessity of air for the growth of pea seedlings.

38. How we can determine whether or not oxidation takes place in living things. We know that sugars, starches, fats, and proteins are in such a form that oxygen can unite with them, when they are heated, and energy can be released from them. What process, therefore, goes on in plants and man that results in the release of various forms of energy? Can we give further proof that oxidation takes place inside living things as it does outside? Since all these food substances contain carbon and since oxidation of any substance containing carbon results in the formation of carbon dioxid, we have a sure method of determining whether or not the oxidation of carbon takes place in living things.

EXERCISE 24

Does the human body give off carbon dioxid? Laboratory demonstration.

Blow the breath through a glass tube into a test tube partly filled with limewater.

1. Describe what is done and state the result.
2. How many breaths are necessary in order to produce this result?
3. How long is it necessary to pump air through limewater in order to bring about a similar result in Exercise 4?
4. What proof have you that carbon dioxid is formed in the body?
5. What element found in foods must be burned in order to produce carbon dioxid?
6. What substance in the air is necessary to cause the burning of foods and the release of the energy contained in them?

EXERCISE 25

Do sprouting oats, barley, or pea seeds give off carbon dioxid? Laboratory demonstration.

Into the bottom of each of two glass jars that can be sealed (*e.g.* quart fruit jars), place some moist blotting paper, and at one side in each jar put a small wide-mouthed bottle of clear limewater. Into one of the jars place a quantity of actively sprouting oats, barley, or pea seeds, sufficient nearly to reach the top of the bottle of limewater. Seal both jars and put them side by side in a moderately warm place for an hour or two.

1. Give an account of what is done.
2. Describe the difference in the appearance of the limewater in the two jars.
3. What is your conclusion?
4. How does this experiment and the preceding experiment prove that oxidation is going on in seeds and in ourselves?

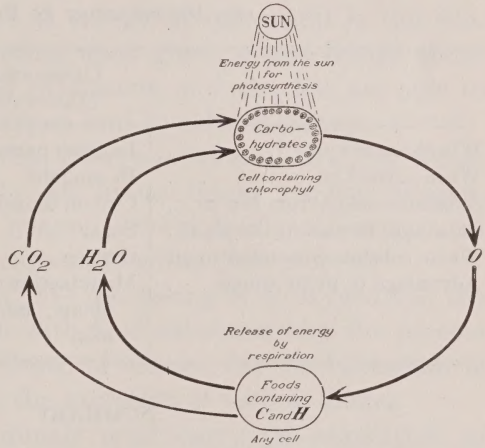


Fig. 37. — Storage and release of energy

39. How energy is released in living things. Our experiments have shown that living things use oxygen, that they form and give off carbon dioxid, and that energy is released. These processes are similar in all living things — plant, animal, and man. The release of energy from fuels and in living things is accomplished by an oxidizing process. This process necessitates the use of oxygen, and there is a consequent formation of carbon dioxid. Therefore, the release of energy resulting from the burning of fuels and that from the oxidation of foods in living things are similar.

The whole series of processes, including the taking in of oxygen, the combining of oxygen with the elements in the food materials (oxidation), the consequent release of energy, and the formation of carbon dioxid, is known as *respiration.* The essential part of the whole series of processes, however, *is the release of some form of energy by oxidation.*

Comparison of Carbohydrate Manufacture (Photosynthesis) and Respiration in Plants

	Carbohydrate Manufacture	Respiration (including oxidation)
Where carried on	In green parts of plants	In all living cells
When carried on	In sunlight	Throughout life
Substance taken from the air	Carbon dioxid	Oxygen
Substance formed in the plant	Sugar	Carbon dioxid
Waste substance excreted to air	Oxygen	Carbon dioxid
Advantage to living things	Manufacture of food for plants, animals, and man	Release of energy

Summary

Work is done when resistance is overcome. *Energy* is required to overcome resistance and therefore to do work.

Some forms of energy are heat, light, electrical, muscular, mechanical, and chemical. Each of these forms of energy can be measured: heat by a thermometer, light by a radiometer, muscular by the weight of matter that is lifted.

The *amount of heat energy* released in living things varies considerably. Plants and cold-blooded animals develop relatively small amounts of heat energy; birds with feather covering and animals with hairy covering constantly keep a temperature of 98° F. or higher.

Foods and fuels have the ability to combine with addi-

tional oxygen. When this union takes place (oxidation), some form of energy is released.

One form of energy can be *transformed*, or changed, into another. When electricity passes through the light bulb, it appears as light energy; when it goes through the motor of a trolley car, it is changed to mechanical energy, and the car is set in motion; when the electrical energy runs into an electric flatiron, the iron is heated.

The ultimate source of energy of our world is the sun. Light from the sun acting upon green plants brings about the production of food substances or fuels that are able to combine with more oxygen and so release energy.

Some of the proofs that energy is released in living things by oxidation are: (1) All living things require oxygen; (2) all living things release several kinds of energy; (3) all living things form carbon dioxid in this process.

Respiration includes: (1) the taking in of oxygen, (2) the combination of oxygen with food substances by the process of oxidation, (3) the release of energy, (4) the formation of carbon dioxid, and (5) the excretion of carbon dioxid.

Both plants and animals must carry on respiration as long as they live. Green plants also carry on food manufacture, or photosynthesis; this process is the exact opposite of respiration in this respect, that in photosynthesis carbon dioxid is taken in and oxygen is given off, while in respiration oxygen is taken in and carbon dioxid is given off.

REVIEW QUESTIONS

1. What is meant by work? What are some examples of work?
2. Define energy and name four forms of energy.
3. Show how any one of these forms of energy may be transformed into another.
4. How can you tell when work is being done? How can you tell when heat, light, or electricity is doing work?

5. What forms of energy are released in living things? Describe experiments that show that plants and man release two or more forms of energy.

6. To what extent is heat energy released in plants? In animals? In man?

7. What is the source of heat and mechanical energy in lifeless things? What is the source of energy in living things?

8. From what source are all the forms of energy named above finally derived? How does energy from this original source come to be in foods and fuels?

9. How is energy released from fuels? How is energy released in living things, and in what three ways did we prove it?

10. Name two uses of food substances. State which of the groups of food substances is used for each purpose.

11. Compare the process of starch making with the processes that go on in a factory.

12. Define respiration. State the most important part of this process to living things. Why is oxygen essential in this process, and why are carbon dioxid and water always formed when respiration goes on?

13. Compare the processes of respiration and photosynthesis.

CHAPTER V

HOW LIVING ORGANISMS ARE CONSTRUCTED

40. Of what parts plants consist. Our ordinary plants consist of roots, stems, and leaves, and at certain seasons of the year flowers, fruits, and seeds are present (Fig. 38). To each of these various parts is given the name *organ*. An organ is a part of a living thing that has a certain work to do, and this work is called its *function*. Roots, for example, are useful to a plant because they hold it in the ground and absorb soil water for it, while stems support the leaves, flowers, and fruit.

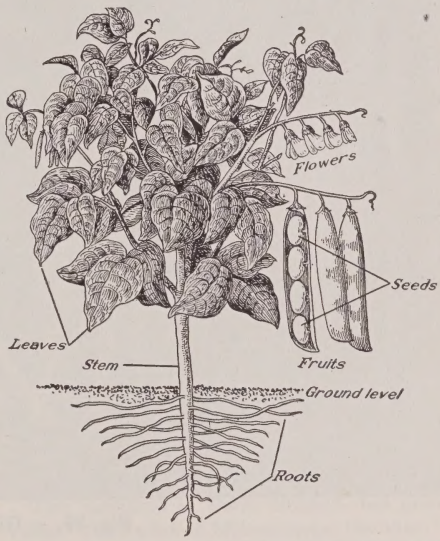


Fig. 38. — Parts of a bean plant
Each part, or organ, has a specific work, or function, to perform.

41. What some of the organs of man and of the higher animals are. In man and in most four-footed and two-footed animals, one can distinguish at least three *regions;* namely, head, neck, and trunk (Fig. 39). To the trunk are attached two pairs of *appendages*, that is, two arms and two legs or, as they are more often called in descriptions of the four-footed animals, the four legs. In the head region are the eyes and the ears,

which enable man and the higher animals to receive impressions of sight and sound from the world about them. With the hands we grasp objects and do intricate pieces of work like writing, sewing, or playing the piano. Hence all

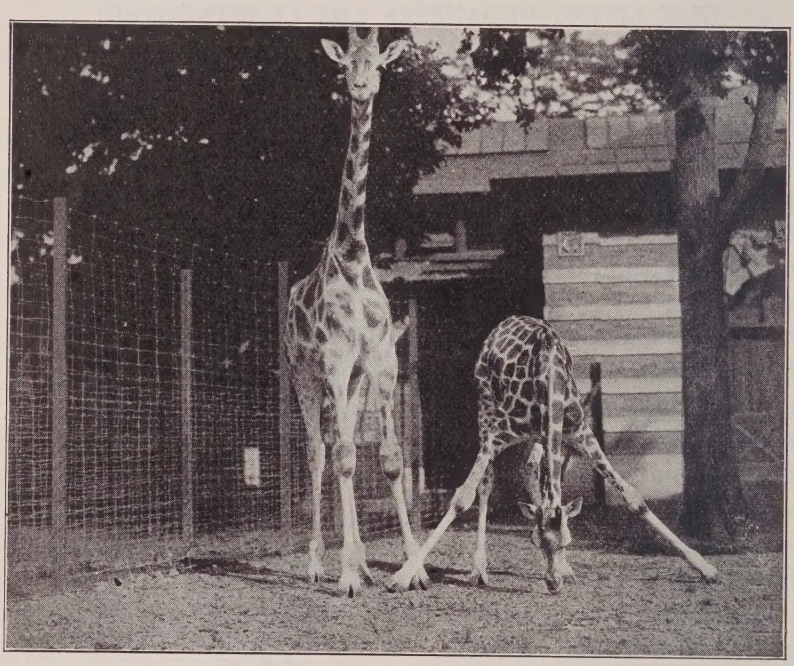


Fig. 39. — Giraffes

Note regions and appendages and feeding position for high trees and for the ground.

these parts of the body, like the parts of plants, are known as organs, each with its function or functions.

42. The history of the study of the microscopic structure of living things. The study of plants and animals was carried on for centuries before the microscope was invented. The earlier biologists, therefore, had no knowledge such as we now possess in regard to the minute structure of

living things. With the invention and development of the compound microscope, however, a flood of light was thrown upon the problems of biology.

Over two hundred years ago a Dutch naturalist, Leeuwenhoek (1632–1723) (Fig. 40), constructed a crude instrument that enabled him to see tiny, hitherto invisible, organisms in stagnant water. About the same time an English physician by the name of Hooke (1625–1703) used the microscope (Fig. 47) to study thin sections of cork (the bark of Spanish oak). He discovered that this plant material was composed of tiny compartments, each enclosed in thick walls. These compartments he called *cells* because of their resemblance in form to the cells of honeycomb. Other biologists later discovered that animal and human bodies are made up of similar microscopical units.

Fig. 40. — Antony van Leeuwenhoek

This merchant of Delft, Holland, has been called "The Father of Microscopical Discovery" because of his observations on "animalcules."

These earlier investigators laid emphasis on the relative form and size of cells, and the *cell walls*, which enclosed the cells, were regarded as all important. Gradually, however, these scientists realized that the material inside the cell was

the real living substance. This substance was called by several names, but finally the name *protoplasm* (from the Greek, meaning *first form*) was universally accepted.

About the middle of the last century (1838) two German biologists, Schleiden (Fig. 41) and Schwann (Fig. 42), one working with plants and the other with animals, developed rather fully the idea that all living things are cellular in structure, and this *cell theory* forms the basis of all modern biology.

From Locy's Biology and Its Makers

Fig. 41. — Matthias Jakob Schleiden (1804–1881)

He elaborated the cell theory as related to plants and may with Schwann (Fig. 42) be called co-founder of this theory that has revolutionized our study of organic life.

43. The general structure of a cell. When a thin section from any part of a plant or animal is examined under a compound microscope that magnifies as many as 100 times, the plant or animal cells seem to have only length and breadth (Fig. 43), and the cell walls appear as straight or curved lines. When one carefully raises or lowers the lenses (as in focusing), it becomes evident that every cell has a certain depth, or thickness, and that walls enclose the whole cell, just as the peel covers an orange.

If the cells are treated with certain stains, a part of the

content of each cell becomes more deeply dyed, and thus we are enabled to see clearly a dense and a less dense portion of the cell contents. To the denser portion, more or less spherical in shape and commonly situated near the center of the cell, is given the name *cell nucleus* (Fig. 43). In some kinds of cells the nucleus is evident even without the use of a stain. To the rest of the cell content is given the name *cell body*, which includes not only protoplasm but also the lifeless food substances within the cell.

Fig. 42. — Theodor Schwann (1810-1882)
The author of the cell theory of organic structure and function, the discoverer of "pepsin," and the first to apply experimental methods of the physicist to investigations of the animal machine.

EXERCISE 26

What is the microscopic appearance of plant cells? Laboratory study.

1. Strip off from the layers, or thickened leaves, of the inside of an onion bulb pieces of the thin skin, or *epidermis*. Cut this into small pieces with scissors under water in a watch glass, and transfer a piece to a drop of iodine and water on a glass slide. Cover with a cover glass and examine with the low power of the compound microscope. Make a careful drawing of three adjacent cells as they look when magnified 100 or more times. Place beneath the drawing the general label, "Cells from an onion membrane, considerably magnified". Label the parts of one of the cells: "Cell wall," "Cell body," "Cell nucleus."

2. Mount a piece of the onion membrane on a slide in a drop of water without the iodine and examine under the compound microscope. What is the natural color of the cell body and the cell nucleus?

EXERCISE 27

What is the microscopic appearance of certain cells of the human body? Laboratory study.

1. Rub gently with a clean finger tip the mucous lining of the mouth. Stir the finger tip in a drop of iodine and water on a glass slide to remove the cells and cover them with a cover glass. Examine with the low and then with the high power of the microscope. Find several cells that resemble one another and make a drawing of one of them magnified

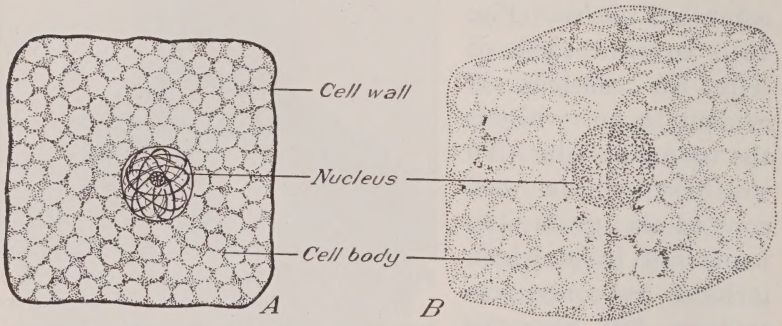


Fig. 43. — Diagrams of a cell

A. **A cell as it appears when seen through the compound microscope.** *B.* **A cell as it would appear if a large model were made of it.**

either 100 or 500 times. Label the cell membrane, cell body, and cell nucleus. Label the whole drawing, "Cells from the lining of the human mouth, highly magnified."

2. Mount some of the cells without the iodine in a drop of water and examine with the microscope, focusing carefully. What is the natural color of the cell body and the cell nucleus?

44. What the characteristics of protoplasm are. Protoplasm, when examined with the highest powers of the compound microscope, commonly appears as an almost colorless, semifluid substance, in which are often seen solid particles, or granules, probably little masses of food materials (Fig. 43). The nucleus is often found near the center of the cell. The appearance and the composition of the protoplasm

may be compared to that of raw white of egg. But in making this comparison, one should bear in mind that the white of egg is not living substance. Biologists now understand *a cell* to be *a bit of protoplasm, usually consisting of two parts: a cell body* and *a cell nucleus*. There may be no definite cell wall, but there is at least a limiting membrane covering the outside of the cell.

45. What assimilation and growth mean. In order to make protoplasm, the plant, animal, or man must have

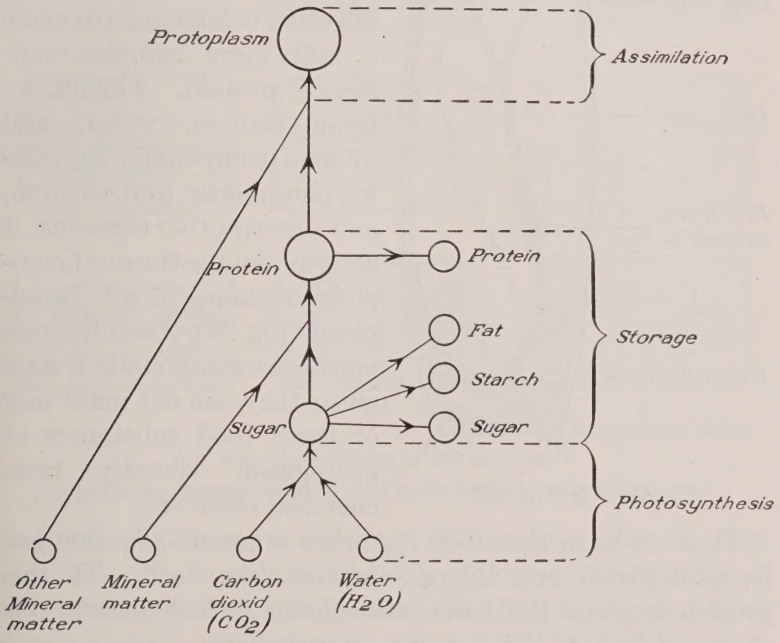


Fig. 44. — Diagram of food manufacture, storage, and assimilation

proteins, water, and additional compounds containing iron, calcium, and several other chemical elements. These must be supplied from the environment or be manufactured by

plants. But so far as we now know, only protoplasm has the power to combine these compounds in such a way as to form living matter.

Bearing in mind the facts we learned in food manufacture, we see that a plant begins with simple compounds (carbon dioxid and water) and manufactures a more complex substance (sugar). It uses this sugar and other substances (nitrates, sulphates, phosphates, and possibly other compounds) to make a still more complex substance, protein. Finally, by using protein, water, and mineral compounds containing phosphorus, iron, calcium, and several other elements, it ends by making the most complex substance of all, protoplasm (Fig. 44). But all plants must have compounds to start with; they can not make any of these food substances or protoplasm, directly from chemical elements.

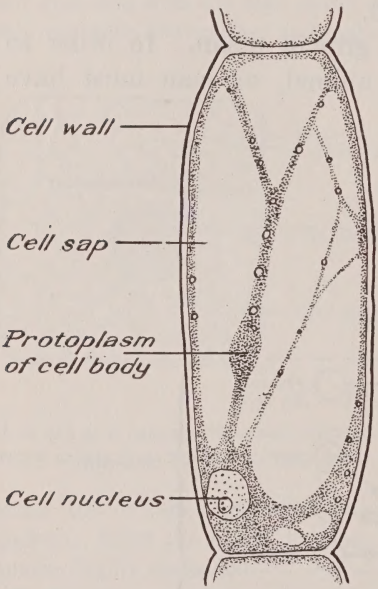
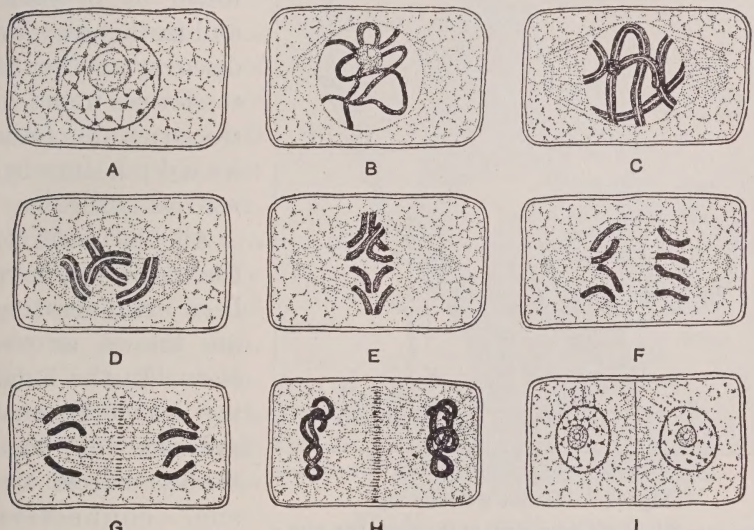


Fig. 45. — A plant cell

Thus we learn that food materials are gradually changed by protoplasm into living substance like itself. To this process is given the name *assimilation*, which denotes *the change of foods to living matter, or protoplasm.*

46. How cell division is carried on. As a result of assimilation, the amount of protoplasm increases, and the cell grows. Were this process to continue indefinitely, cells would become large enough to be seen with the naked eye.

This, however, does not occur. For when a cell of a plant, of an animal, or of the human body reaches a certain size, the nucleus divides by a complicated series of changes (Fig. 46), and the halves of the nucleus separate from each other to form two nuclei. Cell walls are formed between the two nuclei, and so the cell body is divided into two parts,



From Gager's Fundamentals of Botany

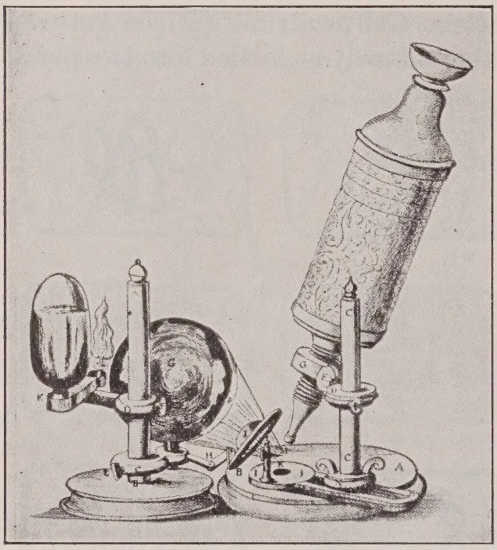
Fig. 46. — Stages in cell division

Describe the changes that take place in the nucleus during this process.

each having its own nucleus. These two cells in turn assimilate, grow, and divide. In this way the number of cells increases with the growth of the plant, animal, or human being.

47. What some of the tissues of the human body are. When we pinch the hand, we feel the hard *bones* that form the skeleton. We can raise from the bones the softer fleshy material, which is composed of *muscles* covered with

skin. By clenching the fingers tightly, we can see and feel on the inner side of the wrist the tough cords, or tendons, of *connective tissue,* which attach the muscles to the bones. If we pinch the hand, we have a sensation either of touch or of pain, and in this way we discover another of the tissues found in the structure of our hand; namely, *nervous* tissue.



From Carpenter's The Microscope and Its Revelations

Fig. 47. — Hooke's microscope

Compare this crude instrument of the year 1665 with a modern microscope (Fig. 48).

All the parts of the hand we have been enumerating are known as *tissues.* In the hand we have found evidence of bone tissue, muscle tissue, connective tissue, and nerve tissue. Other kinds of tissue also are present in the body. Biologists have proved that each tissue is composed of cells and that between these cells is material made by the cells, called *intercellular substance* (*e.g.* the hard part of bones and the elastic part of cartilage, or gristle). See Fig. 50. A *tissue,* therefore, may be defined as *a building material of an organ, composed of cells of the same kind together with more or less intercellular substance that may be present.* The tissues of higher animals are similar in structure.

48. What some of the tissues of plants are. The various organs of a plant are likewise composed of tissues. We have already studied onion membrane, which is a skin, or *epidermal*, tissue. By dissecting the stem of a weed or the twig of a tree (Fig. 51), we find on the outside several layers that make up the bark. Within the bark is a stringy or woody material, and in the center is soft pith. *Pith* is a plant tissue, and the bark and wood are made up of several tissues.

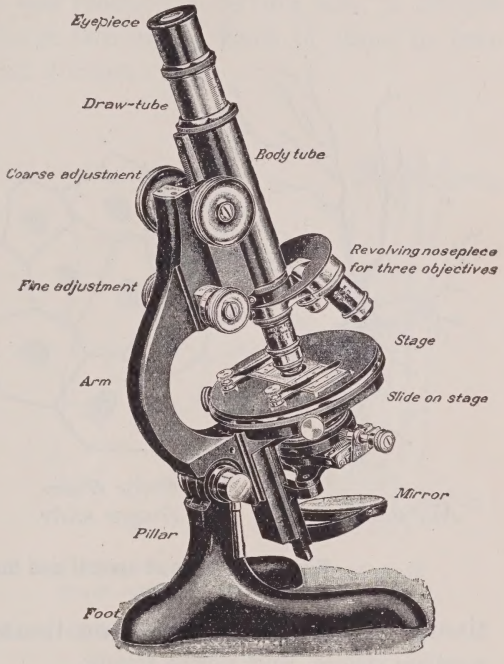


Fig. 48. — A modern microscope

Summary

Living things are composed of *organs*. An organ is a part of a living thing that has some work to do. This work is called its *function*. Among the organs of plants are roots, stems, leaves, flowers, fruits, and seeds. Some of the organs of our bodies are hands and feet, eyes and ears.

Organs are composed of *tissues*. A tissue is a building material of an organ, composed of cells of the same kind together with more or less intercellular substance. Among

the tissues of plants are epidermal tissue, pith tissue, and the tissues that make up bark and wood. Some of the

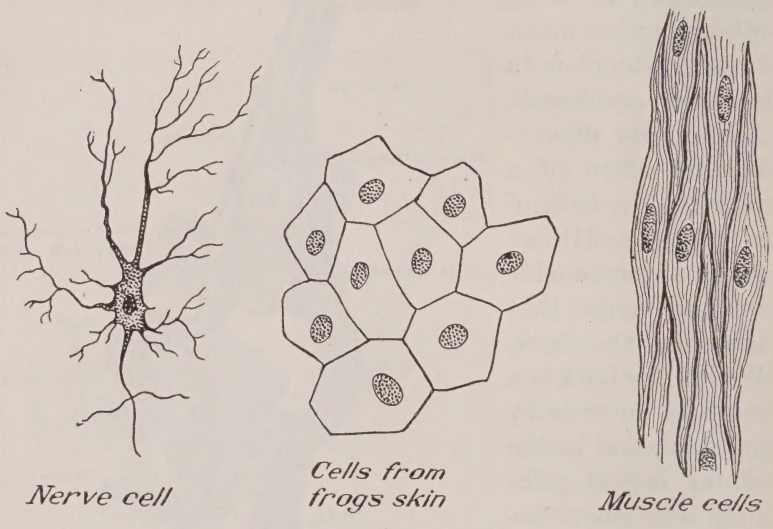


Fig. 49. — Cells of animal and human tissues

tissues of our bodies are bone tissue, muscle tissue, connective tissue, and nerve tissue.

Tissues are composed of *cells*. A cell is a bit of *protoplasm*, usually consisting of two parts, a *cell body* and a *cell nucleus;* a *cell wall* may or may not be present. Among the scientific investigators who have contributed much to our knowledge of cell structure are Leeuwenhoek, Hooke, Schleiden, and Schwann.

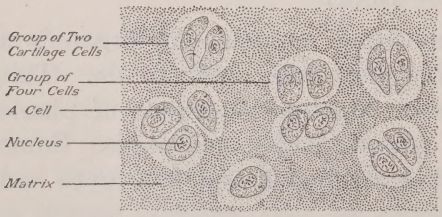


Fig. 50. — Cartilage tissue
The matrix is intercellular substance.

Assimilation is the process by which foods are changed to protoplasm. As a result of assimilation a cell grows larger, and, when it has reached a certain size, it divides (by *cell division*) to form two cells. Each of these in turn assimilates, grows, and divides.

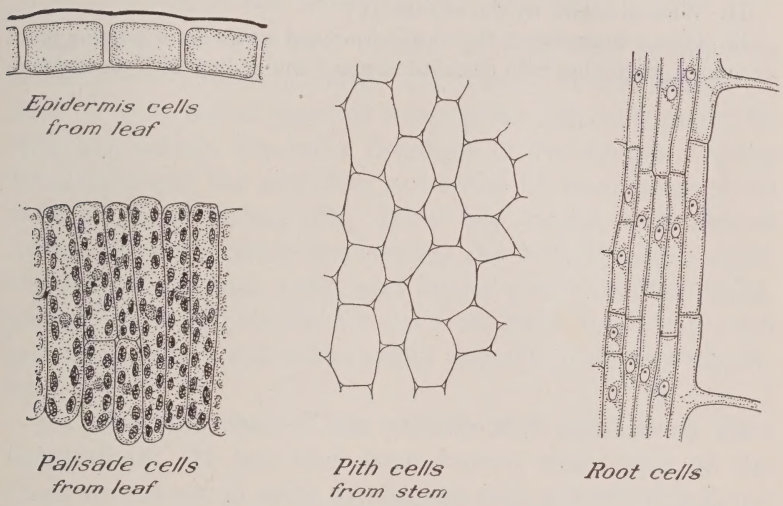


Fig. 51. — Cells of plant tissues

REVIEW QUESTIONS

1. Define the term "organ." Name several organs of plants; of animals; of man.

2. Name several biologists who first studied the microscopic structure of living things and state the contributions made by each.

3. How was material prepared for our microscopic study? What advantage is gained by staining cells?

4. Name and describe the position and appearance of the three parts of a plant or animal cell.

5. Draw the cell of an onion epidermis; a cell from the lining of the mouth. Label each kind of cell and the parts of each of the cells.

6. Give the characteristics of protoplasm. How does the protoplasm of the cell nucleus differ from that of the cell body?

7. What constitutes a cell?

8. Name the successive steps by which chemical compounds are built up into protoplasm. Define the term "assimilation."

9. State the order in which the parts of a cell divide.

10. Name four of the tissues found in the human hand; two found in a plant. Define the term "tissue."

11. What is meant by the cell theory?

12. Give a summary of the composition and structure of a living plant or animal, beginning with chemical element and ending with protoplasm.

CHAPTER VI

WHAT WE SHOULD EAT AND WHY

49. Why we eat and drink. Among our commonest sensations are those of hunger and thirst. These sensations lead us to secure at more or less regular intervals materials that will satisfy the inner demands of our bodies. These sensations and the activities prompted by them seem to be common to all animal life. If for any reason, as in case of illness, these sensations are lacking, the body loses in weight, the person becomes weak, and finally death results. Likewise, if it is impossible for an individual to obtain food and drink, the result is the same; namely, death by starvation.

50. How the uses of the various food substances were determined. It has long been known that some of the foods we eat are in some mysterious way converted into the substance of our bodies, and as a consequence we grow. From foods and oxygen too we secure the necessary energy to carry on our daily tasks. It is only in recent times, however, that scientific investigations have solved many of the mysteries concerning the part played in the body by the different food substances.

In the first place, the five distinct classes of food substances named in **19** were discovered in the foods we eat. Next, by trying many feeding experiments on animals and man, scientists demonstrated the particular uses of each of these food substances (Fig. 52).

51. What the uses of the various food substances are. As a result of scientific work of this sort we find that each

of the five classes of food substances of which all our foods consist can be put into one or the other of two groups:

From Sherman and Smith's The Vitamins

Fig. 52. — Effects of two simple diets

"These two rats were twin sisters and at weaning time were of equal size and equally healthy and vigorous. One was then fed with bread and apple, the other with bread and milk. The former remained stationary while the latter grew to five times the initial weight. The bread was identical in the two diets and the apple was of as good quality as the milk. It can not be supposed that the apple had injured the rat inasmuch as this rat had survived others of the same litter which received bread alone or bread and meat. The difference in result was due to the superiority of the milk over the apple as a nutritional supplement of bread. In the case of the rat thus stunted by confining to a diet of bread and apple, as in most cases of human malnutrition, the fault of the diet was partly in its vitamin content and partly in other factors, conspicuously in this case a deficiency of calcium and phosphorus."

first, those that supply us with energy by the process of oxidation; and, second, those that provide materials for building up the body.

The principal food substances that act as storehouses of energy (the *fuel foods*) are the carbohydrates and fats (or

oils) — food substances that do not seem to be used in the building up of protoplasm. If, however, the body is not supplied with a sufficient amount of these fuel foods, proteins may also be oxidized to furnish us with energy. Water and mineral matter can not, of course, serve as fuel since they can not be burned.

For the building up of protoplasm, on the other hand, proteins are absolutely essential since without them growth and repair cease and death finally results. For protoplasm building certain mineral compounds are also required even though in small quantities. Some of the necessary elements furnished by these compounds are phosphorus, calcium, and iron. Water too in considerable amounts is always present in living protoplasm and must, therefore, be supplied in the diet. For making the hard parts of the teeth and the bones, phosphates and carbonates of lime are two of the necessary minerals.

From Sargent's Plants and Their Uses

Fig. 53. — Bean plants

The seeds are a rich source of protein.

In recent years substances that are neither fuels nor building materials for the manufacture of protoplasm have been discovered in foods. These substances are known as *vitamins*. Their functions are concerned with the regulation of growth and with the healthy development of the body.

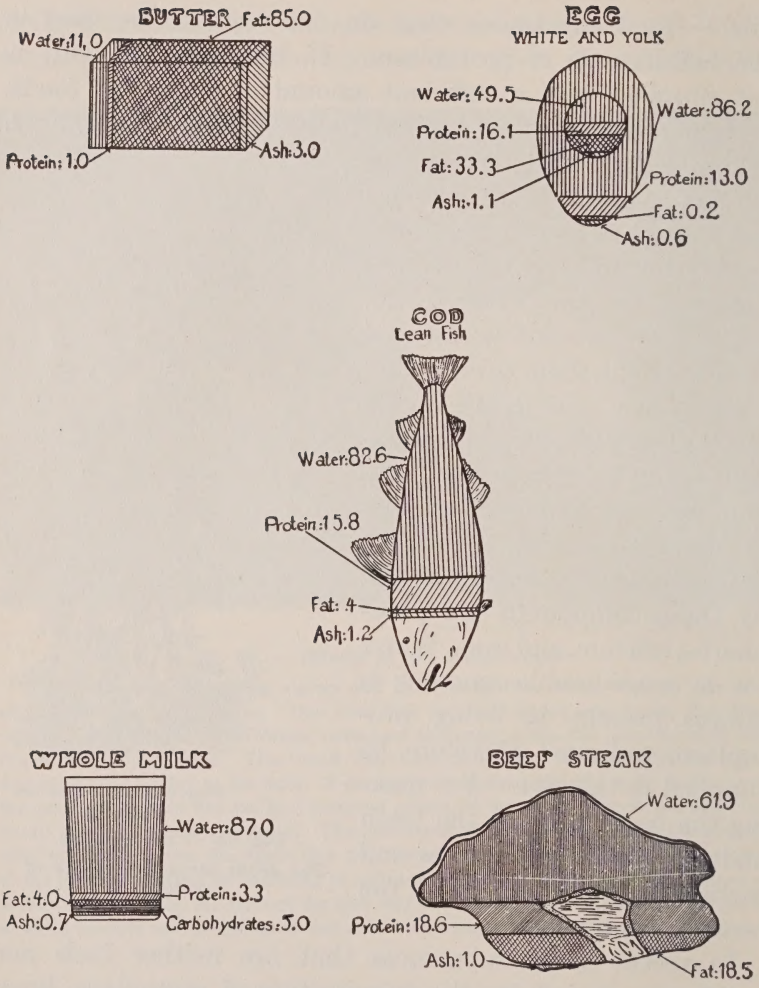


Fig. 54. — Foods derived from animals

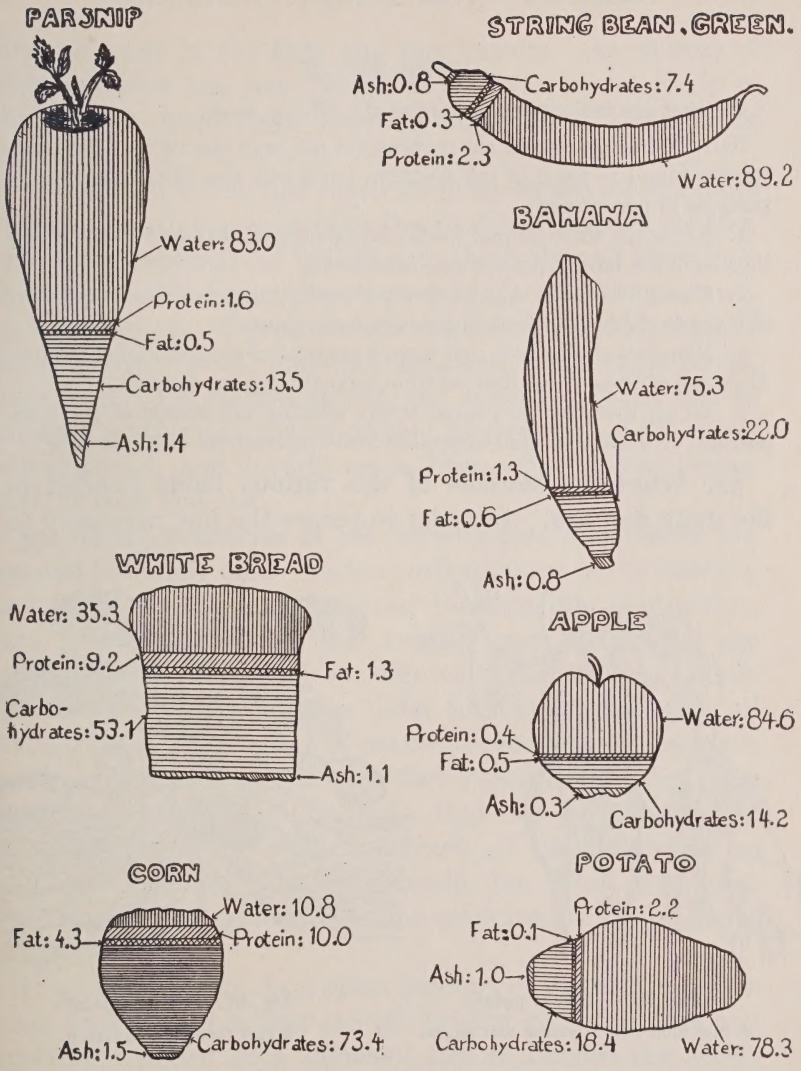


Fig. 55. — Foods derived from plants

EXERCISE 28

Of what are various foods composed? Home work.

NOTE. In Figs. 54, 55 are represented not only the various food substances found in some of our common foods but also their relative proportions in percentages.

1. Name the three animal foods and two vegetable foods on the charts that have the largest percentages of proteins.

2. Name five foods that have 4 per cent or more of fats. Are more of these foods derived from animals or from plants?

3. Name all of the foods that have 4 per cent or more of carbohydrates. Are more of these foods derived from animals or from plants?

4. What, therefore, are three rather striking differences in the composition of the animal and vegetable foods represented on the charts?

52. What the sources of the various foods needed in the daily diet are. In order to secure the fuel necessary to

Fig. 56. — Sweet potato
A fuel food rich in starch and sugar.

Fig. 57. — White potato
A fuel food rich in starch.

furnish the energy we need, we must have foods rich in fats and carbohydrates. As examples of foods containing considerable fats we may select butter, milk, bacon, olive

oil, and most of the nuts and nut butters. As sources of carbohydrates we may choose any of the cereal foods or the breads made from them, potatoes, and, to a lesser degree, milk.

In addition to the fuel foods we must secure for our daily consumption foods to supply the proteins, mineral matter, and water required for building up the body and keeping it in repair. A few examples of such foods that have a fairly high percentage of proteins are the following: the flesh of animals (beef, pork, mutton), fish, and fowl; eggs, beans, peas, and, to a certain extent, the cereals. Foods rich in mineral matter are the vegetable greens, or salads, whole wheat bread, and breads made from other whole grains, such as corn and rye.

53. What quantities of the various food substances are needed in a daily diet. Various investigators in our country and in Europe have determined the amounts of proteins, fats, and carbohydrates that healthy men on the average consume while engaged in different occupations. While the results of these studies differ in some respects, in all the averages the amount of carbohydrates recommended is much greater than that of either proteins or fats. One authority, for instance, asserts that for an adult man at moderate work twice as much of carbohydrates as fats and proteins together should be eaten and that the relative amounts of fats and proteins should be about equal.

If an engine is to do a great amount of work, it must be large enough and strong enough for the given purpose and must be supplied with sufficient fuel to furnish the necessary energy. A man who does strenuous muscular work needs enough proteins, water, and mineral matter in his diet to keep his tissues in good condition and a generous

supply of fats and carbohydrates to act as fuel. The clerk, the bookkeeper, or the student, however, needs considerably less of the fuel foods.

54. Why it is that many people without any scientific knowledge of diet are healthy and vigorous. Undoubtedly there are many scientific truths that seem to have no direct relation to human welfare. If this were true of scientific knowledge concerning the diet, the discussion that is to follow might well be omitted from a high school biology. But such is not the case.

We all know that, when one is ill, special attention must be given to the nature, the preparation, and the amount of food that is eaten. Is this true likewise if one wishes to keep in a state of health? There is no doubt that there are many people who know very little about the reasons for eating certain kinds of food or about the relative value of different foods, and yet they are vigorous, healthy, and happy. A careful study of the diet of such people will show that they are actually getting the kinds of food and about the quantity of each food substance needed to keep their bodies in a state of health. In other words, they are doing the right thing without knowing why. They are following in most cases food choices learned from their parents. Now this knowledge gained through experience probably serves us well so long as we continue to eat the same kinds of foods and in the same way.

55. Why a knowledge of food values and of diet is important. But suppose it is difficult to get the accustomed food either through lack of money or because foods sold under the same name have different composition. In order to economize, for instance, families often use less milk than formerly, evidently regarding this food as a luxury. In fact there is an unfortunate tendency to decrease the

amount of milk used on account of its increased cost. This is poor economy as we shall see.

Again, because of the cost of butter fats, many substitutes for butter are used, which consist of vegetable or animal fats flavored to taste like butter. These "butters" can be sold more cheaply, and many people buy them for this reason, thinking that the source of the fat they eat makes no difference. It is important to remember, however, that vegetable fats lack vitamins. The leafy parts of plants in the form of salads and greens are also often omitted to a considerable extent either because of lack of appreciation of their importance or because of the high cost of such foods.

Then too there are the numerous prepared breakfast foods and breads made from various grains, which, though they may have the same names as formerly, have not the same composition as when the whole of the wheat, corn, or rye was ground up to form flour or meal. In order to get whole wheat, corn, or rice in these days, one may have to pay a higher price for the product and make a special effort to get it.

Thus for one reason or another we may change our traditional diet without being aware that we are depriving ourselves of some essential food ingredient. If, however, the housewife knows the dangers that result from eating grains deprived of essential food substances and if she appreciates the importance of supplying plenty of milk, butter, and green foods, it is reasonable to suppose that she would plan the family diet accordingly.

56. How protein deficiencies in our diet may be made good. It was formerly supposed that one kind of protein was as good as another and that the only matter of importance was to get *enough* proteins. The work of recent

investigators, however, shows that the *kinds* of proteins eaten are as important as the *amounts* if not more so; for, if the right kinds are not eaten and in the right proportions, growth is interfered with or may even be stopped (Fig. 58). To supply possible deficiencies in the proteins we eat, milk

From McCollum's Newer Knowledge of Nutrition

Fig. 58. — Rats fed on different proteins

"The rations of these two rats had the same composition as shown by chemical analysis. They differed only in the source of the protein which they contained. The rat on the right grew up on a mixture of proteins from the corn kernel and wheat gluten; that on the left on a mixture of corn proteins and gelatin. The difference in size and remarkable difference in appearance is solely the result of the difference in the quality of the proteins in the two diets. . . . These animals were the same age when photographed, and had been confined for the same number of days to the experimental diets."

is recommended since it has the necessary proteins in better proportions than any other single food.

57. How mineral deficiencies in our diet may be made good. When wheat or rice are treated in such a way as to remove the outer coats, as is done in polishing rice and in preparing wheat flour, valuable mineral matter as well as other needed substances are removed. To make up for this loss, one should eat considerable quantities of the leafy parts of plants (*e.g.* spinach, lettuce, and cabbage), since they contain the required mineral matter in the best proportions.

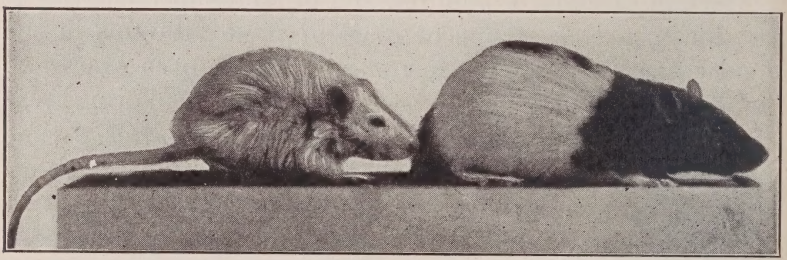
58. How vitamin deficiencies in our diet may be made good. In 51 we mentioned a group of substances found in natural foods that differ in function from any of the five classes of food substances. These substances are called *vitamins* because of their great importance in vital, or life, activity. Their composition has not yet been determined.

Certain diseases of children and of adults are believed to be due to a lack of one or more of these vitamins in the food eaten. *Scurvy,* for instance, has long been known to be due to a deficiency in the diet. Anyone suffering from this disease becomes gradually weaker until after a time he is unable even to sit up, and in extreme cases death results. Sailors on long voyages formerly were subject to this disease even when they had plenty of substantial foods that contained sufficient fats, carbohydrates, and proteins if at the same time they were deprived of fresh meats, fruits, and vegetables. When these fresh foods are supplied to those who are ill with scurvy, their strength returns and the disease soon disappears. Bottle-fed babies are likely to develop scurvy when they drink milk which has been heated as in Pasteurization. The heat seems to destroy the milk vitamins that prevent scurvy. The remedy here lies in giving a little orange juice or the juice of tomatoes.

Another disease due to a lack of a vitamin is an *eye disease* that may lead to blindness. This disease seems to be due to the lack of a vitamin found in butter fat or the fat in the yolk of an egg but not present in other animal fats or in vegetables. Two young rats, as nearly alike as possible, were fed exactly the same rations except that one received a vegetable fat and the other butter fat (Fig. 59). While the latter developed normally, the one without butter fat was less than half the size of its mate and developed

the eye disease. If the experiment is carried too far, blindness results. When, however, 5 per cent of butter fat was supplied, the young animal rapidly recovered and became normal.

Beriberi is a nerve disease rather common in the Orient. It has also occurred in Labrador and occasionally in other



From McCollum's Newer Knowledge of Nutrition

Fig. 59. — Rats fed on different kinds of fats

"The rations of these two rats from weaning time were exactly alike except in the character of the fat which they contained. The one on the left was given 5 per cent of sunflower seed oil. The one on the right was given 1.5 per cent of butter fat. Butter fat, egg yolk fats and the leaves of plants contain a dietary essential, the chemical nature of which is still unknown, which is necessary for growth or the maintenance of health. This substance is known as fat-soluble A, and is not found in any fats or oils of vegetable origin. A lack of this substance in the diet causes the development of a peculiar eye disease known as xerophthalmia. The animals were the same age when photographed."

parts of the world. This disease seems to result when polished rice or white bread is used to the exclusion of fresh meat and fresh vegetables. The polishings from rice are found to contain vitamins. When these are added to the diet, the sufferers very soon recover. Leafy parts of plants also contain the vitamins that prevent beriberi.

Rickets is a disease of the bones of children, which results from a diet in which certain vitamins are lacking. Cod-liver oil is a known remedy for this disease.

Milk, butter fat, eggs, fresh fruits, and the leafy parts

of plants are sometimes called the *protective foods*, because they make good the protein, mineral, and vitamin deficiencies that are likely to occur in our diet.

59. What simple rules should be followed in choosing one's diet. It would seem, then, to be comparatively easy for parents or even for a boy or girl to choose a hygienic diet, for, unless one is sick, one need only heed the following simple directions:

(1) *Eat a variety of plant and animal foods* in sufficient quantity to satisfy the normal appetite, but do not overeat.

(2) *Include in the diet a liberal amount of the protective foods* — milk, butter fat, fresh vegetables and fruits, and the leafy parts of plants in the form of greens, or salads.

(3) *Drink plenty of water* — at least a quart a day. Drink at meals if you desire but not while food is being chewed.

(4) *Include in the diet a number of foods that have a good deal of cellulose* — the coarser vegetables, fruits, whole wheat bread, or bran biscuits — to supply "roughage."

Summary

Food substances serve either for tissue building or for fuel foods. The uses of each of the five classes of food substances were discovered by scientific feeding experiments. The fuel food substances are carbohydrates and fats — though proteins may be used in this way. Tissue-building food substances are proteins, certain mineral substances, and water.

To be healthy and vigorous, one must eat the right kinds of food in the right proportions. Everyone needs more carbohydrates and fats than proteins and minerals. If a person is doing hard muscular work, he needs an increased amount of fuel foods.

We can not rely on appetite in the choice of a diet or on the experience of family or race because foods having the same names as in former times may not have the same content on account of methods of manufacture. Knowledge of food values is necessary in the choice of a diet.

Protein deficiencies occur because many suppose one kind of proteins is as good as another. *Mineral deficiency* may occur because many foods are deprived of their mineral content either by manufacture or by method of cooking. *Vitamin deficiency* is rather common because the natural foods that contain the vitamins are not eaten.

DEFICIENCIES IN FOODS AND THEIR RESULTS

DEFICIENCY IN	FOODS TO MAKE GOOD THE DEFICIENCY	HARM DONE OR DISEASE CAUSED BY DEFICIENCY
Protein	Milk	Growth hindered or stopped
Mineral	Leafy parts of plants, whole grains, and vegetables	Growth hindered or stopped. Teeth and bones can not develop
Vitamins	Milk, butter, cream, yolk of eggs, fresh fruits, whole grains, leafy parts of plants	Eye disease, rickets, scurvy, beriberi

REVIEW QUESTIONS

1. What happens if the sensations of hunger and thirst are lacking?
2. How were the uses of each of the five classes of food substances determined?
3. What are the uses of each of the classes of food substances?
4. What are vitamins, and why are they necessary?
5. State some of the principal sources of each of the classes of food substances.
6. How should the amount of each food substance vary for men in different occupations?

7. How should the amount of carbohydrates compare with the amount of protein in the daily diet?

8. Which classes of foods should be increased in amount if a boy or girl is to engage in hard muscular work or in training for some trying athletic event?

9. How can you explain the fact that many people are healthy and vigorous and yet lack a scientific knowledge of diet?

10. Why is a knowledge of food values and diet particularly necessary in these days?

11. Why do people limit their supply of milk, grain foods, and butter fats?

12. Why is the kind of protein just as important as the amount?

13. How may a protein deficiency be made good?

14. Why is one likely to fail to get the right kind of mineral food substances in a proper proportion?

15. How may one be sure of making good any mineral deficiency?

16. Name and describe four diseases due to lack of vitamins in diet.

17. What foods will supply the vitamins that will prevent each disease referred to in question 16?

18. Describe the experiment in feeding rats which shows the effect of a lack of butter fat in the diet.

19. State the four simple rules that should guide every boy and girl in choosing a diet.

CHAPTER VII

HOW DRUGS AND BEVERAGES AFFECT US

I. General Discussion of Drugs

60. What substances other than foods are taken into the body. In the preceding chapter we discussed food substances, and these we learned yield material for making protoplasm, for regulating growth, or for supplying the fuel necessary for the release of energy in the body. But in addition to the various food substances that may be used for one or all of these purposes, each one of us takes in certain compounds, known as *food accessories*, that have little or no value as foods in any of the three ways named above. As examples of such substances, we may mention flavoring extracts, spices, and common salt, all of which are eaten because they add to the enjoyment of our foods. They are also directly useful in stimulating the appetite and in increasing the flow of

From Sargent's Plants and Their Uses

Fig. 60. — Pepper plant

Black pepper is prepared by grinding the dried berries.

the digestive juices. Tea, coffee, and cocoa belong in this group of food accessories.

61. What effect tea and coffee produce on the body. We take tea and coffee for their agreeable flavors and because they have a stimulating effect on the nervous system, largely due to the presence of essentially the same substance (*drug*) in both; namely, *caffein*. This acts principally on the nervous system. From both tea and coffee also, if they are boiled for some time or if allowed to stand on the grounds for more than a few minutes, another substance is extracted, which is known as *tannin*. When tannin is taken into the alimentary canal, it is found to injure the mucous membrane and to retard digestion.

Fig. 61. — Tea plant
The leaves of this plant are dried and used in preparing the beverage.

"It is probably safe to say that, when used in moderation, tea and coffee are probably harmless *to adults* leading an otherwise hygienic life. They should be used sparingly by nervous people and by those in whom digestion is feeble and slow. Even by the perfectly healthy they should not be used to excess, nor should the habit be acquired of using them as a whip to the tired horse. Drinking strong coffee in order to keep awake for evening study is objectionable, and the substitution of afternoon tea for a little rest or sleep is also unwise." [1]

[1] Hough and Sedgwick's *The Human Mechanism*, p. 156.

62. What effects chocolate, cocoa, and soda water produce. While it is true that cocoa and chocolate both contain a considerable amount of nutriment when eaten in solid form. when prepared as a beverage, the small amount so used makes their food value relatively unimportant unless milk is used. Chocolate and cocoa [1] contain a certain amount of a stimulant similar to that found in tea and coffee. Since the sirups and ice cream used in the preparation of soda water contain a considerable amount of sugar, these drinks should not be taken to any considerable extent between meals, because they tend to impair digestion and to lessen the appetite at mealtime.

Courtesy of N. Y. Botanical Garden

Fig. 62. — Cacao tree

Cocoa and chocolate are prepared from the fruits of this tree.

63. What some of the dangers in the use of drugs are. *What is meant by drugs, stimulants, and narcotics?* It is important, at the very beginning of our discussion, to keep clearly in mind that by a *drug* we mean not only those contained in medicines that we buy of an apothecary but also any substance that tends to have an abnormal effect on

[1] Cocoa is chocolate from which a part of the cocoa butter has been removed; hence it is less rich, that is, less greasy and therefore easier to digest.

the body, either by unduly increasing its activity, as do *stimulants*, or by decreasing or depressing activities, as do *narcotics*. Tea and coffee and especially alcohol are

From Sargent's Plants and Their Uses

Fig. 63. — Coffee tree

The two-seeded berries of this plant are used in preparing the beverage.

oftentimes taken to drive a weary nervous system to action. Instead of a stimulating whip of this sort, rest and proper food would be far better and more effective. Other substances, such as morphine and cocaine, produce results

just opposite to those of stimulants, that is, they cause a depressing, or narcotic, effect.

We must remember that, while man and other animals have always required proteins, fats, and carbohydrates, it is only with the development of human ingenuity that drugs have been made available. In most cases they are unnecessary except in illness, and they may do a great deal of harm, as is unquestionably true of alcohol, cocaine, and morphine.

From Sargent's Plants and Their Uses

Fig. 64. — Opium poppy

The drugs opium, morphine, and laudanum are prepared from the milky juice that comes from the seed pods.

In the first place, drugs are often taken to get rid of weariness, pain, or other bodily *symptoms;* instead the victim should seek to remove the *cause* of the difficulty. Pepsin tablets, for instance, may be used to prevent indigestion, but they surely do more harm than good if we fail to get at the real cause of the indigestion. It is most dangerous, too, for a person to rely on sleep-producing drugs; instead he should remove the troubles of body or mind that induce the sleeplessness.

In the second place, those who continually use drugs like opium, cocaine, tobacco, or alcohol are almost sure to become slaves to these substances and are quite likely to

find that increasing quantities of the drugs are necessary to satisfy their cravings. "There are people who are slaves of tea, of chocolate, of patent medicines, of candy, and of certain soda fountain drinks, just as truly as there are slaves of tobacco, of alcohol, or of opium. It is worse to be the slave of alcohol than of coffee because the evil consequences of alcohol are greater than those produced by the corresponding use of coffee; but it is by the same process in both cases that the man or woman becomes a slave to the drug, and that process is the formation of bad habits." [1]

In the third place, the use of drugs, or even of stimulants like tea and coffee, by the young is to be regarded as unfortunate. Vigorously growing protoplasm is very sensitive to stimulants and narcotics of any kind (see **74**). These substances are not needed by young people in health, and, if used to any considerable degree, they tend to interfere with the normal development of the nervous system and of other parts of the body. More than this, if stimulants are needed later in life in cases of emergency, they will prove less effective if the body has already become accustomed to their action.

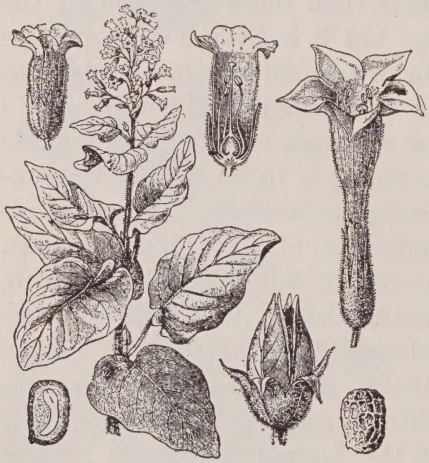
II. The Effects of Tobacco

64. What effect tobacco has on growth. In the discussion of the effects of tobacco it is important, as was the case with tea and coffee, to distinguish between the results of its use by the young and by adults. Just because his father seems to be using tobacco without harm is no reason why a boy can safely smoke. We have already called attention to the complex composition of protoplasm. During the whole period in which the body is attaining its growth, this living substance is affected far more appreciably and

[1] Hough and Sedgwick's *The Human Mechanism*, p. 355

seriously by the use of stimulants and narcotics than is the case later in life.

Tobacco contains a drug known as *nicotine* which is a narcotic in its effects; that is, it tends to decrease both activity and growth. That such is its effect during early life has been abundantly proved in many ways. But perhaps the most conclusive facts are those presented by actual measurements made in college gymnasiums. Dr. Hitchcock of Amherst College, who made careful measurements of college students for a good many years, found that those who did not smoke increased in height during their college course 37 per cent more than those who did smoke, and in chest girth the difference was 42 per cent, or nearly one half as much again. Dr. Seaver of the Yale gymnasium found, also, that in height and lung capacity smokers were considerably inferior to those who did not use tobacco.



From Sargent's Plants and Their Uses

Fig. 65. — Tobacco plant

The dried leaves are used for smoking or chewing or as snuff. Insecticides and fertilizer are also derived from the plant.

65. How tobacco affects mental development. Dr. George L. Meylan, Director of the gymnasium of Columbia University, made a careful comparison, during two years, of the relative physical measurements, rate of growth, and scholarship of 115 college men who smoked and 108 men

in the same class who were nonsmokers.[1] He found (1) that the smokers were on the average eight months older, which means that they had entered college this much later; and (2) that "the scholarship standing of smokers was distinctly lower than that of the nonsmokers," showing "that the use of tobacco by college students is closely associated with idleness, lack of ambition, lack of application, and low scholarship." Dr. Bastedo, author of one of the most widely used books on drugs, says: "Idle and ambitionless boys are more prone to be smokers early in life than are ambitious and hardworking boys."

Dr. M. V. O'Shea of the University of Wisconsin has recently (1923) published a book, *Tobacco and Mental Efficiency*, in which he speaks as follows: "The testimony of principals and high school teachers is uniformly to the effect that tobacco is a detriment to scholarship in the high school. . . . School records studied over a long period of time corroborate the testimony of principals and high school faculties. When a pupil begins the use of tobacco, the chances are that his intellectual work will decline in comparison with a boy who abstains from tobacco. . . . A few investigations of the effect of tobacco on the scholarship of college and university students lead to the conclusion that tobacco is a detriment to the intellectual work of college students as well as of high school pupils. . . . Many of the men who have given testimony regarding the effect of tobacco on their own intellectual processes state that they believe tobacco is injurious to immature persons. . . . The consensus of opinion in all groups is very strongly against the use of tobacco in any form by young persons."

Dr. Andrew D. White, for twenty years president of Cornell University, out of his wide experience in education,

[1] *Popular Science Monthly*, August, 1910.

gave the authors his opinion as follows: "I never knew a student to smoke cigarettes who did not disappoint expectations or, to use a vernacular expression, 'kinder peter out.' I consider a student in college who smokes as actually handicapping himself for his whole future career. I am not fanatical in regard to smoking. It seems to me possible that men who have attained their growth and are in full health and strength may not be injured by moderate smoking at times. I will confess to you that at one period of my life I was a smoker myself, though in a very moderate degree. And should you feel a strong desire to smoke, thinking it may rest you and change happily at times the current of your thought, I may perhaps commend to you my own example; for I began my smoking at the age of forty-five and ended it ten years ago at the age of seventy."

66. What effect tobacco has on athletic success. One of the rules rigidly enforced in athletic contests is that all candidates must abstain from the use of tobacco while in training. The reason for this insistence is the fact that tobacco seriously interferes with the nervous machinery of the heart and also affects breathing; therefore, those who smoke are found to be easily "winded" in the games.

An investigation[1] was carried on among the football squads of fourteen of the American colleges and universities to determine the relative success of the smokers and nonsmokers who tried for positions on the varsity teams.

"Six institutions furnished data relating to the 'try outs.' A total of 210 men contested for positions on the first teams; of this number 93 were smokers, and 117 were nonsmokers. Of those who were successful, 31 (*i.e.* 33%) were smokers, and 77 (*i.e.* 65%) were nonsmokers. It

[1] "Smoking and Football Men," *Popular Science Monthly*, October, 1912.

will be observed that only half as many smokers were successful as nonsmokers. . . ."

Hence, the ambitious boy, who has any regard for developing a vigorous body fitted for athletic success, for training a mind capable of clear thinking, and for preparing himself for a successful life work, will resist all temptations to smoke, at least until he has attained his full growth.

III. The Effects of Alcohol

67. Alcohol as a possible food. Like the carbohydrates and fat, alcohol is composed of carbon, hydrogen, and oxygen. Since it contains no nitrogen, it has no value in the processes of growth and repair; in other words, it can not be made into protoplasm. But is it a food in any sense?

Alcohol we know may be burned in lamps for the production of heat and in engines for the generation of power. Professor Atwater has shown that alcohol also, if used in sufficiently small amounts, may produce within the human body a certain amount of heat and muscular power and possibly other forms of energy. Indeed, in some cases of extreme weakness, especially in diseases, alcohol is regarded by some eminent physicians as necessary for saving life, though even for this purpose it is now being used to a less extent in medical practice.

68. What the general effect of alcohol is. On account of the amount imbibed, however, alcohol, as ordinarily used in beverages, is practically always either a stimulant or a narcotic. Dr. Bastedo, whom we have already quoted as an expert on drugs, says, "Alcohol is probably never a source of energy (and therefore never a food) unless the body is already short of food, as in very sick people. Its ordinary use socially, even in small amounts, is to make one

more careless about the responsibilities of life — a very dangerous use of it, since it lessens judgment and reasoning power. It therefore sets free the lower instincts which are ordinarily kept in check by our higher faculties."

In later sections we shall discuss the effects of alcohol on various organs of the body. One fact should, however, be continually emphasized; namely, that, even if it should be taken for granted that alcohol, when used by *adults in moderation*, may generate a certain amount of energy, still *this is an exceedingly dangerous compound* to introduce in any form into the diet of a boy or girl. In the first place, it interferes with the healthy growth of protoplasm; and, in the second place, the use of liquors *in moderation* by a great many people, both young and old, is absolutely impossible. Men never become drunkards, paupers, and criminals by taking the nutrients, starch, sugar, fat, and protein, nor does the taste for any one kind of food become uncontrollable, as is so often the case with alcohol. Till he has tried it, no one can be sure whether he can control his appetite or not. When he has ascertained the fact, it is often too late. The child should be taught to avoid alcohol because it is dangerous to him. The only certain safety for the young lies in total abstinence.

69. What effects small and large quantities of alcohol have. The effects of alcohol on the body depend very largely upon the quantity taken; if the amount is small, alcohol may possibly be regarded as a source of energy and hence, in a very limited sense, as a food; in larger amounts it seems to increase temporarily the activity of the organs of the body, and so it apparently becomes a stimulant; if still larger quantities are taken, the narcotic effects of alcohol result in complete insensibility; and, finally, a sufficient amount may be consumed to poison the organs and

cause death. No one who begins the use of alcohol expects to take such an amount as will act as a poison or even as a narcotic. There is, however, a constant danger that one will do so.

70. How Professor Hodge carried out his experiments with dogs. During the years 1895–1900, Professor Hodge of Clark

From Physiological Aspects of the Liquor Problem

Fig. 66. — From left to right: Bum, Tipsy, Nig, and Topsy

The appearance of the four spaniels six months after the experiments were begun. Can you tell by their appearance which dogs were fed alcohol?

University carried on some very instructive experiments upon dogs. He secured four spaniel puppies (Fig. 66), born on Washington's birthday, 1895; the two males were brothers, and the females sisters. Professor Hodge carefully watched the four for nearly two months before beginning his experiments in order to pick out the two most vigorous animals; these he named "Tipsy" and "Bum." He put in with the chief meal of these two each day a moderate amount of alcohol; it was not enough, however, to cause any evidence of intoxication. The other two spaniels,

"Nig" and "Topsy," received no alcohol. For over five years these dogs were studied, and important facts were learned as to the general effect of alcohol on physiological processes.

71. What effect a moderate amount of alcohol had on the activity of the dogs. Early in his observations it became evident to Professor Hodge that the dogs that were receiving the alcohol were far less playful than were those that had no alcohol in their food. To measure the comparative activity of the different animals, he attached to the collar of each dog a Waterbury watch adjusted in such a way that it would tick once each time the animal moved, and so at the close of each day he could determine and set down the record made by each dog. He found that for a period of two months and more Bum was only 71 per cent as active as Nig, and Tipsy was only 57 per cent as active as Topsy; in other words, the two alcoholic dogs lost 25 per cent to 50 per cent of their activity.

72. What effect a moderate amount of alcohol had on the skill and endurance of the dogs. A second series of experiments was made to determine the comparative endurance of the four dogs and their ability to accomplish things. The animals were all taught to retrieve a rubber ball when it was thrown the length of the gymnasium floor, a distance of 100 feet. On each day the ball was thrown 100 times, and a record was kept of which dogs started for the ball and of which one succeeded in bringing it back. When he had averaged a long series of experiments, Dr. Hodge found that Bum and Tipsy secured the ball only about half as often as did Nig and Topsy; the two alcoholic dogs also gave evidence of much greater fatigue during the trials.

73. What effect a moderate amount of alcohol had in producing nervousness. "A very striking result of the entire research," says Dr. Hodge, "and one entirely unexpected on account of the small doses of alcohol given, has been the extreme timidity of the alcoholic dogs. . . . While able to hold their own with the other dogs in the kennel, the least thing out of the ordinary caused practically all the alcoholic dogs to exhibit fear, while the others

evinced only curiosity or interest. Whistles and bells in the distance never ceased to throw them into a panic in which they howled and yelped, while the normal dogs simply barked. This holds true of all the dogs that had alcohol in any amount."

74. **What effect a moderate amount of alcohol had on the offspring of the dogs.** Another most striking result of the use of

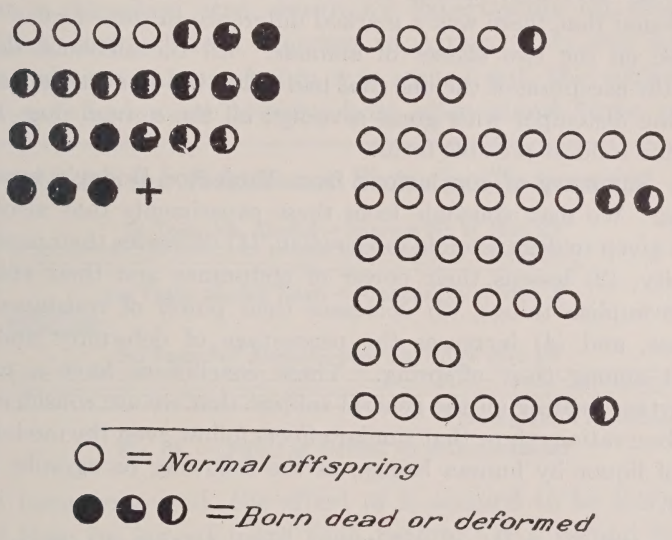


Fig. 67. — Comparison of offspring
At the left, the puppies of Bum and Tipsy; at the right, the offspring of Nig and Topsy.

alcohol was shown in its effects on the young of Bum and Tipsy. Of the twenty-three puppies descended from these alcoholic animals only 17 per cent lived to be normal dogs; the rest were either deformed or unable to nourish themselves, and all died soon after birth. On the other hand, of the forty-five young of Nig and Topsy over 90 per cent were healthy puppies. Hence, the puppies of the dogs that were given alcohol even in moderation were over *five times* as likely to be born dead or to die young as were the puppies born of parents that had no alcohol (Fig. 67).

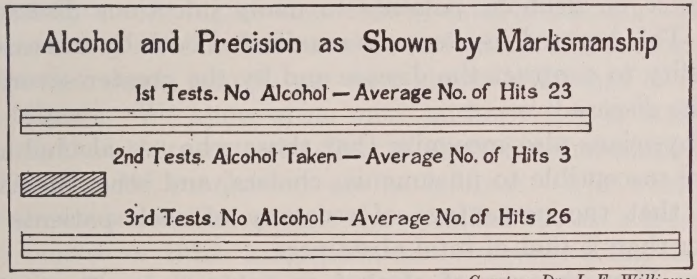
75. What effect a moderate amount of alcohol had on resistance to disease. In the spring of 1897, in the course of these experiments, a great many dogs throughout the city of Worcester were afflicted with distemper, and dogs sick with the disease were not uncommon on the streets. At that time, Dr. Hodge had, in all, five dogs that were taking alcohol and four that were not. It was found that there was a marked difference in the effect of the disease on the two classes of animals. All the alcoholic dogs, with the exception of the one that had taken the smallest amount, had the distemper with great severity; all the normal dogs had it in the mildest possible form.

76. Summary of conclusions from Professor Hodge's experiments. We may conclude from these experiments that alcohol, when given to dogs, even in moderation, (1) decreases their natural activity, (2) lessens their power of endurance and their ability to accomplish things, (3) decreases their power of resistance to disease, and (4) increases the percentage of deformity and of death among their offspring. These conclusions have a most important bearing on the general subject that we are considering, for observations show that similar effects follow even the moderate use of liquor by human beings, as the following paragraphs will show.

77. What effect the moderate use of alcohol has on the mental activity of man. "Few causes are more effective in leading to the abuse of alcohol than the idea that when one finds difficulty in doing a thing it may be accomplished more easily by having recourse to beer or wine or whisky for their 'stimulating' effect. In general, so far is this from being the truth that the person seeking such aid is really using a hypnotic and a depressant. Obviously he would be acting more wisely to adopt other methods of accomplishing his end. Nor is this conclusion merely theoretical. Brain workers who wish to 'keep a clear head' almost universally avoid alcoholic drinks, at least

until work is over. And even among those who do drink it is customary to avoid drinking until the day's work is done." [1]

78. What effect a moderate use of alcohol has on the muscular activity of man. That the general effect of alcoholic drinks on muscular activity is a depressant rather than a stimulant was shown by experiments on English soldiers during forced marches in Africa. "It was found that, when a ration of rum was served out, the soldier at first marched more briskly, but, after about three miles


Alcohol and Precision as Shown by Marksmanship
1st Tests. No Alcohol — Average No. of Hits 23
2nd Tests. Alcohol Taken — Average No. of Hits 3
3rd Tests. No Alcohol — Average No. of Hits 26

Courtesy Dr. J. F. Williams

Fig. 68. — Effect of alcohol on marksmanship

had been traversed, the effect of it seemed to be worn off, and then he lagged more than before. If a second ration were given, its effect was less marked and wore off sooner than that of the first. A ration of beef tea, however, seemed to have as great a stimulating effect as one of rum, and not to be followed by any secondary depression." [2]

79. What effect a moderate use of alcohol has on the manual dexterity of man. A German scientist determined the effect of alcohol on four typesetters in the following way: "Four days were used for the tests, the first and third of which were 'normal days,' the second and fourth were 'alcohol days.' On the alcohol days each man received

[1] Hough and Sedgwick's *The Human Mechanism*, p. 364.
[2] Quoted from T. Lauder Brunton.

about seven ounces of a Greek wine . . . a quarter of an hour before the trials took place." On the "alcohol days" it was found that the amount of type set was on the average 15 per cent less than that set on the "normal days."

80. What relation exists between the moderate use of alcohol and disease. "A much larger number of the victims of alcoholic intemperance die of some infectious disease than of the special alcoholic infections. Attention has been repeatedly called in this article to the lowering of the resistance of alcoholic patients to many infectious diseases. . . . This lowered resistance is manifested both by increased liability to contract the disease and by the greater severity of the disease." [1]

Physicians also recognize that those who use alcohol are more susceptible to pneumonia, cholera, and other diseases and that the percentage of recovery of such patients is lower than is that of total abstainers.

81. How the use of alcohol as a beverage affects the length of human life. In 1922 the New York Life Insurance Company published a study made by Dr. Oscar H. Rogers, Chief Medical Director, on "The Effect of Alcohol upon Longevity." In this pamphlet Dr. Rogers makes use of all the available life insurance statistics which relate to the question of habits in the use of alcoholic drinks. He first compares abstainers with those who use alcohol, though always in moderation. It has been the practice among a number of life insurance companies, especially in England, to insure total abstainers in a class by themselves, so that the companies which follow this method are in a position to compare the longevity (length of life) of those who use alcohol with that of total abstainers from its use. After putting all of this statistical material to-

[1] Dr. Welch in *Physiological Aspects of the Liquor Problem*, Vol. II, p. 372.

gether, Dr. Rogers shows that the mortality, or death rate, in a group of nonabstainers (that is, those who take alcohol) is 32 per cent higher than that in a similar group of abstainers. This means that 132 nonabstainers die to every 100 deaths among abstainers.

Let us now turn to the results of a study of about 6,000,000 lives from the records of life insurance companies doing business in the United States. Dr. Rogers shows that temperate daily users of alcoholic drinks showed a death rate 18 per cent higher than that of total abstainers; while free users of alcohol, but never to the extent of intoxication, showed a death rate 86 per cent higher than that of total abstainers. We know of no more authoritative or striking figures than these as to the effect of alcohol in shortening life.

Dr. Rogers' conclusions are as follows: "The evidence before us is conclusive that the so-called Anstie's limit of 1½ ounces or three tablespoonfuls of alcohol a day is far too liberal. Indeed, there appears to be no limit within which alcohol may be entirely harmless. It is as if there were a direct relation between the amount of alcohol used and the amount of damage done to the body. The evidence is strong also that the damage done persists a long time after drinking has been discontinued. Anyone who uses alcohol now or has used it in the past is a less desirable insurance risk, all other things being equal, than a total abstainer, and his undesirability is in proportion to the liberality with which he has used the drug."

82. How the Volstead Act interprets the Eighteenth Amendment. The Eighteenth Amendment to the Constitution of the United States became the law of the land on January 16, 1920. By this amendment the manufacture and sale of intoxicating liquors as a beverage were prohibited. In the minds of many there seems to be a confusion

between the provisions of the Eighteenth Amendment and those of the Volstead Act. The Eighteenth Amendment, which is now a part of the Constitution, does not define an "intoxicating liquor." The Volstead Act, passed by Congress, declares that any beverage containing over one half of 1 per cent of alcohol should be regarded as intoxicating. Hence, the manufacture of even wines and beers, both of which contain 3 to 5 per cent of alcohol, is illegal.

It is of course too much to expect that the use of alcohol throughout our country, and especially in the large cities, will cease at once. Many people who have become slaves to alcohol will take dangerous and even illegal chances in order to satisfy their cravings. Since prohibition went into effect, cheap and especially poisonous substances have been added to liquors. Anyone, therefore, who purchases alcoholic drinks these days runs a grave risk of taking liquors containing wood alcohol or other deadly ingredients.

83. Concluding remarks on the use of alcoholic beverages. "In the foregoing pages we have stated the salient facts concerning the physiological action of alcohol and alcoholic drinks. It only remains to point out for the student the obvious conclusions to be drawn from them and from the long and, on the whole, very sad experience of the race with alcoholic drinks. The first is that, except in sickness and under the advice of a physician, alcoholic drinks are wholly unnecessary and much more likely to prove harmful than beneficial. The last is that their frequent, and especially their constant, use is attended with the gravest danger to the user, no matter how strong or self-controlled he may be. . . . The only absolutely safe attitude toward alcoholic drinks is that of total abstinence from their use as beverages." [1]

[1] Hough and Sedgwick's *The Human Mechanism*, p. 370.

IV. The Dangers in Patent Medicines

84. Why many patent medicines are dangerous. Headache medicines usually contain a chemical (*e.g.* acetanilid) which reduces the heart action and so relieves the pain by diminishing the blood pressure without removing the cause of the pain; for the real cause may be disordered digestion or eye strain. Cases of permanent injury and even of death have resulted from taking these headache compounds (Fig. 69). They should never be used except under the direction of a competent physician.

BEWARE OF ACETANILID

A large proportion of the most common headache medicines sold at drug stores depend for their effectiveness on the heart-depressing action of acetanilid. In some cases three or more grains of this drug are present in each dose.

The Pure Food and Drug Law requires all makers of patent medicines to indicate clearly on the labels of such preparations the presence of acetanilid and other dangerous compounds. Hence one has but to read the labels and avoid these nostrums in order to protect himself.

Take no headache remedy without consulting a doctor, unless you are sure it contains no acetanilid or other heart depressant. Make the druggist tell you. He is responsible.

Fig. 69

In most soothing sirups and cough medicines are found substances derived from opium, which is a powerful narcotic. Hence, children who are given soothing sirups often become stupefied. If these compounds are given frequently, they injure the child permanently and in larger doses have caused death. If cough sirups and like compounds are taken often, an opium habit may be developed, and this is even more difficult to overcome than is the alcohol habit.

Fig. 70 represents the percentage of alcohol contained in

three "patent medicines" as given by the Massachusetts State Board of Health in published document No. 34, as compared with the percentages of alcohol found in whisky, champagne, and beer. The stomach bitters (Fig. 70), for example, contained over eight times as much alcohol as was found in beer. Hence, the average drug store where these patent medicines are freely sold must share with the

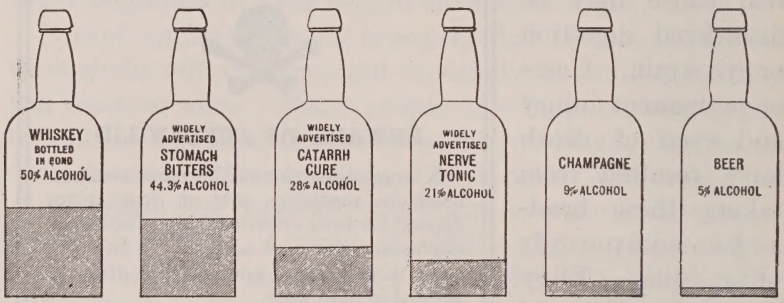


Fig. 70. — Percentage of alcohol in patent medicines and in liquors.

"bootlegger" and the illegal liquor saloon the heavy responsibility for the prevalence of the drink habit.

85. Pure Food and Drug Law. One of the most important laws passed by the 59th Congress of the United States was that which requires every manufacturer of foods or medicines to state on the label the amount of alcohol and of any poisonous drug in the composition of each. Analyses of foods and drugs have proved that hitherto many of them were largely adulterated by cheap and often injurious compounds, put in to increase the manufacturers' profits. Then, too, many patent medicines contain high percentages of alcohol and other dangerous drugs. Under this law the purchaser, if he takes the trouble to read the printed label, can determine what he is putting into his body, in so far as certain of the poisonous drugs are concerned.

Summary

Food accessories are substances taken into the body to give flavor to the foods or to stimulate the appetite. Examples are tea, coffee, spices, flavoring extracts, and salt.

Tea and *coffee* contain *caffein*, which acts as a stimulant. These beverages, when properly made, probably do not harm *adults*, if taken in moderation. They should not form a part of the diet of boys and girls.

A *drug* is any substance that tends to have an abnormal effect upon the body. Drugs that increase activity are known as *stimulants;* those that decrease activity are known as *narcotics*. The repeated use of drugs is dangerous because so often the user becomes a *slave to the habit.*

Tobacco is a narcotic. Its use retards the growth of the young, decreases lung capacity, and seriously interferes with scholastic and athletic success.

Alcohol, while apparently a stimulant when used moderately, is really always a narcotic in its effects. It is one of the most dangerous of the habit-forming drugs.

Careful experiments and observations on human beings have proved that even a moderate use of alcohol (1) interferes with mental activity, (2) decreases muscular activity and skill, (3) lessens resistance to disease, and (4) shortens the average length of life.

Patent medicines are likely to be dangerous because they frequently contain alcohol, opium, or other habit-forming drugs.

REVIEW QUESTIONS

1. Give several examples of food accessories. In what ways do these substances differ from foods?
2. Why do human beings use tea and coffee? What drugs are found

in these beverages, and what is the effect of each on the body? What cautions should be exercised in the use of tea and coffee?

3. What is meant by a drug? Name two classes of drugs, and give examples of each. In what way does each of these classes of substances affect the body?

4. How do drugs differ from foods? Discuss each of three ways in which drugs may be a source of danger to man.

5. What can you say as to the effects of certain patent medicines? To what drugs are these effects due?

6. What is the effect of tobacco on growth? How and by whom were these facts determined?

7. Discuss the relation of tobacco to mental development.

8. What is the effect of tobacco on athletic success?

9. Discuss the possible differences in the effect of tea, coffee, and tobacco on the young and on adults.

10. In what way does alcohol possibly resemble a food? How does this substance differ from a food?

11. How does the moderate use of alcohol by human beings affect (1) mental activity, (2) manual dexterity, and (3) muscular activity? Describe definite experiments in each case.

12. What is the relation between (1) moderate use of alcohol and disease, (2) total abstinence and life insurance?

13. What are two grave dangers in even a moderate use of alcohol?

14. Give reasons why patent medicines are likely to be dangerous.

15. How does the Pure Food and Drug Act help to protect the public?

CHAPTER VIII

HOW FOODS ARE PREPARED FOR DISTRIBUTION AND USE IN LIVING THINGS

86. How we know food materials are transported through plants. Vegetables like potatoes, beets, carrots, and onions grow beneath the ground. In testing these foods (Chapter II), we found large supplies of starch or sugar or both. These food materials can be manufactured only in the presence of sunlight by cells that contain chlorophyll (Chapter III). It should be evident, therefore, that manufactured food materials in some form must travel from the leaves where they are manufactured to their place of storage beneath the ground. On the other hand, in order to manufacture carbohydrates and proteins in the leaves, water and mineral matter must travel through the plant from the soil. Hence, food substances move upward and downward through a plant and so must pass into cells and out from cells.

87. How we know food materials are transported through the bodies of human beings and of animals. In the human body every living cell of the muscles or of other tissues must have food for repair or growth and for the release of energy. The same is true of all forms of animal life with which we are familiar. Unlike green plants, our bodies and those of the animals we know can not manufacture these foods, and so they must be taken in at the mouth. In order to reach the various cells of which we have spoken, these food substances must travel through all parts of the body

Moreover, when the various tissues are tested for food substances, we find all classes of them represented. Therefore, food substances in some form must pass into all the cells of the bodies of animals.

88. Questions that might be asked with reference to the movements of food materials in living things. We have just seen that food materials must pass both into and out from cells of plants and animals. Do you think that the presence of cell walls and of protoplasm will help or hinder the passage of these food substances? Do you think that food substances will be more likely to pass from cell to cell in a solid or in a liquid state? Since some of these substances must sometimes move upward directly against the force of gravity, is there any form of energy we can discover that may act in such a way as to overcome gravity? Do any substances with which you are familiar tend to intermingle when they are brought into contact? To some of these puzzling questions we shall find answers in the text and in the experiments that follow.

89. What is meant by diffusion of gases. If a gas like ammonia is set free in one part of a closed room, in a short time the odor of the ammonia will be detected in all parts of the room. Everyone who has had any experience with ordinary illuminating gas knows how quickly this mixture of gases will spread through the air of a room. The process by which gases intermingle is known as *diffusion of gases.* Now it should be noted that diffusion of gases is independent of the action of gravity, or at least it will take place in spite of gravity (Fig. 71). To show this fact we might try an experiment like the following: [1]

Fill a wide-mouthed bottle with illuminating gas by dis-

[1] The teacher may make a class demonstration of each of the experiments that are outlined in this and the following sections.

placement of water (see Fig. 11 and Appendix II). Now, take another bottle of the same size and shape as the first and place it upright on the table. Cover the mouth of the bottle of illuminating gas with a piece of paper, and transfer this bottle to the top of the bottle containing air in such a way as to bring the mouths of the two bottles exactly opposite each other. Withdraw the paper and allow the bottles to stand one above the other for ten or fifteen minutes.

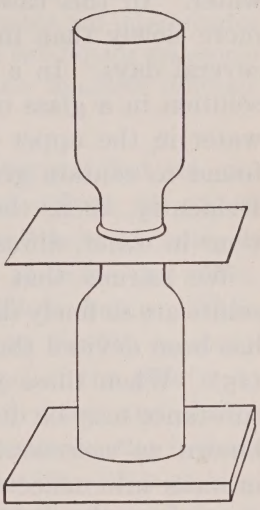


Fig. 71. — Diffusion of gases

This apparatus can easily be prepared.

Let us now see whether the lighter illuminating gas has diffused through the heavier air (Fig. 71). Quickly remove the bottle that was filled with illuminating gas and invert the bottle that formerly contained air only. Plunge a burning taper into this bottle or bring the mouth of the bottle over a flame. The contents will burn, showing that the lighter illuminating gas has diffused downward into the heavier air. If illuminating gas is not available, hydrogen may be used instead.

90. What is meant by diffusion of liquids. In order to show that liquids diffuse, we should first secure some red ink and a glass of water. Fill a pipette with the ink and carefully force it out over the bottom of the glass containing the water. Without disturbing its contents, set the glass aside until the next day. You will then observe that the red ink has moved upward through the water. In other words it has diffused throughout the water in spite of the fact that the ink is heavier than the water.

A similar experiment may be tried with molasses or a dense solution of grape sugar. By means of a large pipette put a layer of the sugar solution in the bottom of a glass of water. In this case complete diffusion takes place much more slowly than in the case of the red ink; it may take several days. In a similar way put a layer of dense salt solution in a glass of water. After five or six days, if the water in the upper part of each glass is tested, it will be found to contain grape sugar or salt, as the case may be. Evidently, then, these substances, which form true solutions in water, diffuse through the water.

We learned that in true solutions the particles of the solute are so finely divided in the solvent that no microscope has been devised that will reveal the presence of the solute (15). When these particles are the smallest into which a substance may be divided and not lose its identity, they are known as *molecules*.[1] Salt and sugar probably break up in water into molecules of salt or sugar and then are diffused throughout the molecules of water. It is believed that this is what happens in all true solutions of solids in liquids.

91. Why diffusion of gases and liquids takes place. In the case of gases it is believed that the molecules possess *inherent energy of motion* (that is, energy within themselves). This energy causes them to be in a constant state of movement. In case the molecules are restrained in an enclosed space like a bottle, this constant movement results in a diffusion or intermingling of the gases.

The same is true of solid substances that are truly dissolved in a solvent like water. In liquids, however, while the solute is broken up into molecules, the energy of these molecules is held in check in some way, and so diffusion of two liquids takes place much more slowly than in the case of two gases. Likewise, in

[1] The molecules of many soluble substances, especially acids, alkalies, and salts, break up partially into smaller electrically charged particles called *ions*.

some solids that dissolve, the intermingling of solvent and solute is much slower than in others.

When a solvent and a solute are stirred together, the diffusion is more rapid, as is the case when sugar is stirred in coffee or tea. This is due to the fact that the two substances are intermingled by external force, and so the surfaces of the two liquids are sooner brought into contact with each other; hence complete diffusion takes place very quickly.

92. Insoluble substances and substances that do not form true solutions in water will not diffuse in water. Place in a glass a tablespoonful of some mineral, such as phosphate of lime, that is practically insoluble in water, and add several tablespoonfuls of (distilled) water. While stirring this mixture draw up in a large pipette as much as possible. Now gently plunge the end of the pipette to the bottom of another glass of distilled water and slowly force out the mixture of mineral and water on the bottom of the glass. Prepare in a similar manner two other glasses, but place in one a mixture of raw white of egg and water and in the other a mixture of starch paste in water instead of the mixture of mineral matter. Cover the three glasses and allow them to stand for five days or more.

If the water in the glass in which the phosphate of lime was placed is then examined, it will be seen that the mineral matter has settled on the bottom of the glass; it shows no sign of having diffused through the water. The same will be found true of the starch paste and of the white of egg. It will be noticed, however, that neither the mixture of white of egg nor that of the starch paste has settled appreciably. It occupies about the same space in the water that it did when first put on the bottom of the glass. If chemical tests are made of the water in the upper part of each of the glasses, no phosphate of lime, protein, or

starch will be found. Evidently then the insoluble mineral matter and the apparently soluble white of egg and starch paste show no appreciable energy of diffusion in water.

93. How substances are classified as to diffusibility. The substances found in living things belong to one of the following groups: (1) gases like oxygen and carbon dioxid that diffuse readily in each other; (2) substances like sugar and salt that dissolve in water and then diffuse slowly; (3) semisolid substances[1] (such as starch and protein) in a very finely divided condition that seem to form solutions in water but really do not and that show little or no tendency to diffuse in water; and (4) solids that do not dissolve nor appear to dissolve and possess no energy of diffusion in water. Which of these kinds of substances will be able to pass into and out from cells?

94. Under what conditions diffusion must occur in living things. Before taking up experiments to show what is true with reference to diffusion into and out from cells, it is necessary to consider the various conditions under which interchange of food substances must take place. First, it must be evident that the substances inside the cells and outside the cells will not be in immediate contact with each other, as were the various substances used in our previous diffusion experiments. Between dead plant cells there will usually intervene a cell wall of cellulose, and in living plant cells there is an additional membrane made up of a layer of protoplasm next to the cell wall (Fig. 45). In living animal cells there will be at least a *membrane* composed of an outside layer of protoplasm, and in addition there may be another membrane (cell wall) made by

[1] Semisolid substances, such as starch paste and proteins, are sometimes called *colloids* (gluelike).

the protoplasm (Fig. 49). Hence, in order to enter or leave living cells, it is evident that food materials must pass through some kind of membrane. Let us, first, try an experiment with cells in which there is no protoplasm but only a dead membrane made up of the walls of animal or plant cells. Now will a solvent (water) and a true solution of a substance in water (solute) pass, or diffuse, through such a membrane?

EXERCISE 29

Will water or sugar in solution pass through a membrane? Laboratory demonstration.

Materials: a thistle tube, a wide-mouthed bottle; honey, molasses, or a thick solution of grape sugar or other reducing sugar; Benedict's or Fehling's solution. Procure the intestines of a calf or a beef, wash them thoroughly inside and out, and blow them up by inserting a large glass tube. Tie at intervals of about two feet, and allow this membrane to dry. Cut off pieces about two inches long and slit open each of the pieces thus obtained. Membranes prepared in this way may be kept for years in closed jars. Sausage coverings that have been preserved in salt also may be used after they have been thoroughly washed and dried. The lifeless membranes we have described are composed of cell walls only. It is, however, much easier to use goldbeaters' membranes if they are available.

Hold the thistle tube upright, closing the smaller end by pressing on it with the thumb or with a piece of rubber tubing closed with a clamp. Into the larger end of the thistle tube pour the honey, molasses, or reducing sugar that has been warmed sufficiently to pour easily. Half-fill the tube and nearly fill the bulb. Moisten one of the pieces of membrane and fasten it tightly over the bulb of the thistle tube by means of elastic bands or a thread so that none of the liquid can escape. Wash off any of the liquid from the outside of the membrane; then dry with a blotter. Hold the thistle tube upside down long enough to make sure that the sugar solution does not leak out.

If Windsor beans are available, the materials within the seed coats can be removed from the hilum region, after the seeds have been soaked for twenty-four hours. The seed coats can then be attached to the smaller end of a thistle tube by an elastic band. The tube can then be filled

with the heated grape-sugar solution. If the solution does not flow easily, a long hat pin may be moved up and down through the tube.

Support the thistle tube, the membrane being down, in a bottle of water (Fig. 72). Mark on the thistle tube with an elastic band the level of the sugar solution and set the experiment aside for fifteen minutes or until the next day. If the experiment is to continue for several days, connect a long piece of glass tubing to the smaller end of the thistle tube and support the long glass tube in a vertical position.

Fig. 72

1. Describe the preparation of the experiment, giving the reason for each step. Make a drawing of the apparatus.

2. State whether or not there is any change in the level of the grape-sugar solution within the thistle tube. Has the water passed through the membrane or not? How do you know?

3. Test the liquid in the bottle for a reducing sugar. State the result. How do you account for the result?

4. What substances have you proved will pass through a membrane composed of cell walls?

5. Which of the two substances passed through the membrane more readily, the water (solvent) or the sugar (solute)? How do you know?

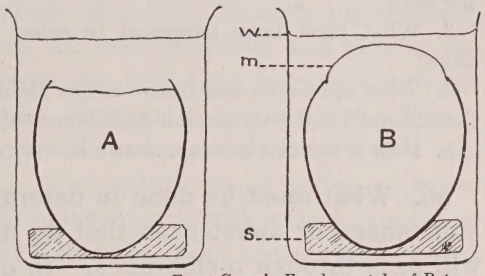
95. Some definitions and explanations. We have seen in the experiment just tried that both water and grape sugar diffuse through a membrane and thus mingle with each other. *Diffusion through a membrane is osmosis.*[1]

We have proved that water passed through the membrane much more rapidly than did the sugar, and this is likewise true in the case of salt and nitrate of potash and other soluble minerals. Hence we see that solvents pass through the membranes more freely than do solutes. In case a membrane is of such a nature that it prevents the diffusion of the solute, while allowing the solvent to pass through freely, the membrane is said to be *semipermeable.* It is

[1] The teacher may set up an experiment in the same way as in Exercise 29 to show that soluble minerals like salt or nitrate of potash will diffuse through a membrane as did the sugar.

said that perfect or ideal semipermeable membranes probably do not exist in nature. Hence, any membrane that interferes with the free passage of a solute, while allowing the solvent to pass freely, is imperfectly semipermeable. Therefore, the membrane used in Exercise 29 with water and sugar is imperfectly semipermeable, since it allowed some of the sugar to pass through.

Now, the fact that the molecules of the solute (sugar) could not diffuse out as readily as the molecules of water diffused in brings about an unbalanced pressure known as *osmotic pressure*, which is said to be always exerted by the solute. The osmotic pressure of the sugar in Exercise 29 caused the water to enter and the mixture to rise in the thistle tube. The mixture continues to rise until the osmotic pressure is the same on both sides of the membrane. Even with an imperfectly semipermeable membrane it is possible to cause a rise of liquid in a tube to a height of six to ten feet. You will, therefore, see how osmotic pressure may help to explain the rise of water in plants where the membranes may be more nearly semipermeable.



From Gager's Fundamentals of Botany

Fig. 73. — Osmosis through egg membrane

A, at the beginning of the experiment; B, about one hour later; w, surface of water; m, egg membrane; s, support of egg. Explain the difference between A and B.

EXERCISE 30

To show osmotic pressure in living cells. Home work.

Peel a portion of a potato. Cut several cross sections of the peeled part of the potato, each about an eighth of an inch in thickness. Allow

these sections to stand in the air until they have wilted on account of the evaporation of water. Now place some of the wilted sections in a glass half filled with clear cool water and set aside for half an hour or more.

1. Describe the way the experiment is performed.
2. Remove one of the sections of potato from the water and bend it between the fingers. How does it compare in stiffness with the sections that have not been put into the water? Which is exerting the greater pressure, the water outside or the solution of minerals and sugar inside the cells?
3. What must have happened to cause this change in the potato slices?
4. What light does this throw on the ability of water to pass through the cell walls and protoplasmic membranes of living cells?
5. How is osmotic pressure shown in the experiment?

96. What must be done to determine whether insoluble substances or substances that do not form true solutions will pass through membranes. In 92 we have shown that insoluble substances like phosphate of lime and insoluble starch do not diffuse appreciably in water. Neither does white of egg, in spite of the fact that it is apparently (though really not) soluble in water. Now the question arises — Is it likely that these substances will diffuse through membranes? The following experiment will help us to answer this question:

EXERCISE 31

Will starch pass through a membrane? Laboratory demonstration.[1]

Set up a thistle tube as in Exercise 29, except that a starch and water mixture is used in the thistle tube in place of the sugar solution. Allow the experiment to stand overnight at least.

1. Describe the experiment or state the difference in the preparation of this experiment and that with the grape sugar.

[1] The teacher may set up several additional thistle tube experiments that will show whether or not proteins, fats, and mineral matter will pass through membranes.

2. How can you determine whether or not starch has passed through the membrane?
3. Make the test and record the result.
4. What is your conclusion from this experiment?

97. What food substances will diffuse through membranes and what will not. Experiments similar to those performed show that water and gases *very readily* diffuse through a membrane and that sugar, common salt, and nitrate of soda in solution also pass through membranes, but *much less freely*. In the case of starch and also in the case of insoluble minerals we find that they will neither diffuse in water nor pass through a membrane. This is likewise true of all other substances, such as proteins and fats, that do not form true solutions in water. Consequently, in our osmosis experiments with starch, proteins, and fats (Exercise 31) we found that none of these substances passed through the membranes, and apparently the water itself did not pass through. We have, however, already shown that water will pass through a membrane when there is a solute in water on the other side of the membrane. We may assume, therefore, that in the case of insoluble substances the water on both sides is interchanging but at an equal rate in both directions. Hence, there would be no change of level in the thistle tube or outside in the bottle.

98. Osmosis in living things. Thus far we have been dealing with lifeless membranes, but in living cells of plants and animals the living membrane formed by the protoplasm (Fig. 45) must be taken into account. It has been discovered that this protoplasm acts as a *selective agency* so that the passage of certain solutes may be prevented, while the solvent may diffuse freely in either direction. Thus the water on the outside of the cell might enter the cell through the membranes rapidly, while the mineral or sugar

solutes inside might not pass outward at all or at one time might pass and at another time might not. This is undoubtedly due to conditions in the membrane of protoplasm. As conditions change within the protoplasm, the osmosis of solutes and of solvents is found to vary. A membrane that acts as just described is semi-permeable, since it allows diffusion of certain substances and not of others.

However, an interchange, whether due to osmotic pressure or not,[1] must go on in the case of each cell of a plant or of an animal, and it is the conditions in the protoplasm that apparently control the entrance and the exit of the solvent water and of the various solutes. We have already seen, however, that osmosis does not take place in the case of starch, proteins, fats, or mineral matter which does not dissolve in water. This is likewise true of all other substances that do not form true solutions in water. Neither can these insoluble substances pass through the living membranes formed by the protoplasm.

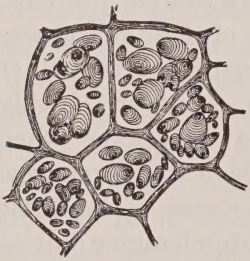


Fig. 74. — Starch grains in cells of a potato

Why can not the starch diffuse through the membrane?

99. Why insoluble food substances must be changed before they can pass through cell membranes. Substances like water, sugar, and some mineral matter in solution can pass from cell to cell in the manner we have described. Starch also, which can only be manufactured by green parts of plants and in the sunlight, at length finds its way to places of storage beneath the ground. But before this food substance, which is in the form of solid starch grains (Fig. 74), can escape from the cells where it is made, some change must take place that will allow it to pass through the cell membranes. We shall

[1] In plants and animals there are cases of absorption of food materials which can not be accounted for by the diffusion energy of molecules. We shall, however, hereafter use the term "osmosis" in discussing the passage of liquids through a membrane without regard to the cause of the diffusion.

now determine by experiment the nature of this change in starch.

EXERCISE 32

Does a growing seedling change its starch so it can pass through cell walls? Laboratory demonstration.

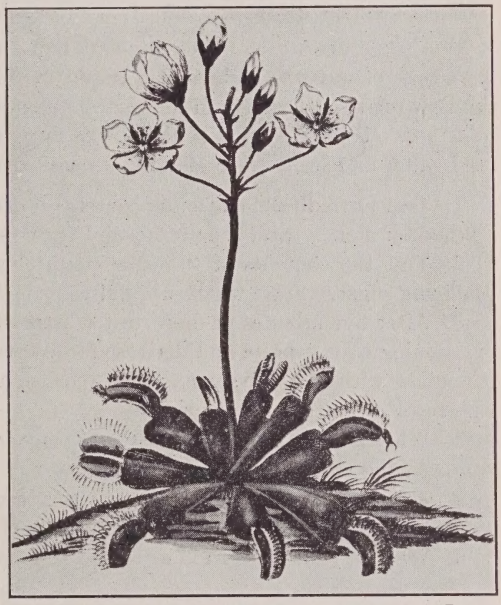
Materials: Dry and sprouted corn (or barley or oats).

1. Test the unsprouted grains for starch and for a reducing sugar. State your observations and conclusions.

2. In a similar way test the sprouting grain for starch and for a reducing sugar. What do you find, and what do you conclude as to the presence of each substance?

3. What change must have taken place in some of the starch?

4. Of what advantage would this change be in the corn plant?



From Gager's Fundamentals of Botany

Fig. 75. — Venus's flytrap

When insects alight on the leaves, the halves quickly close, and the teeth on the edges interlock. The captured insect is then digested by the ferments secreted from the leaf surface by certain cells in this part of each leaf.

100. What is meant by digestion and by digestive ferments, or enzymes. We have seen in the preceding experiment that insoluble starch in seeds is changed to soluble sugar during the process of sprouting. *The change from an insoluble, non-diffusible food substance to a soluble food substance that will*

diffuse through cell membranes is known as digestion. Substances have been found in plants that are able to transform insoluble foods into soluble and diffusible foods. These are known as *digestive ferments*, or *enzymes*. One of these digestive enzymes that has been found in plants is known as *diastase*.

EXERCISE 33

Does diastase digest starch? Laboratory demonstration.

Boil some arrowroot starch [1] (about half the size of a pea) in half a test tube of water to make a thin paste. Cool the mixture and divide it into two parts. Dissolve in half a test tube of water a small amount of diastase. To one portion of the starch mixture add half of the diastase and water and set it aside, shaking it occasionally.

1. Test for reducing sugar the contents of the tube containing diastase and water alone. State the result and the conclusion.
2. Test the contents of the tube containing starch paste alone for a reducing sugar. State the result and the conclusion.
3. After five minutes or more test a part of the contents of the tube containing starch paste and diastase for starch and for a reducing sugar. Compare with the tube containing diastase and water alone. What is the result and what is your conclusion?
4. What change has evidently taken place in some of the starch?
5. At the end of ten to fifteen minutes test the rest of the starch and diastase mixture for starch. What is the result, and what do you conclude? What, therefore, must have become of the starch?
6. What is your conclusion as to the action of diastase on starch?

EXERCISE 34

Does saliva digest cooked starch? Laboratory demonstration.

Prepare some thin arrowroot starch paste as in Exercise 33. Divide the mixture in halves and add some filtered saliva to one half.

1. Test the starch paste and then the saliva for a reducing sugar. Is it present in either? How do you know?

[1] This experiment may be performed successfully with raw starch if sufficient time is allowed for the action of the diastase.

2. After five minutes test the contents of the tube containing both starch and saliva for a reducing sugar. State the result and the conclusion.

3. What is your conclusion as to the action of saliva on cooked starch?

4. How, then, is starch made diffusible in the human body?

5. NOTE (to be copied). In the saliva there is a digestive enzyme, called *ptyalin*, similar to diastase in its action. Ptyalin has no digestive action on raw starch since it can not digest the outer covering of cellulose. Boiling bursts open the cell walls and also the starch grains.

From Gager's Fundamentals of Botany

Fig. 76. — Sundew

Note the sticky hairs (tentacles) on the margins of the leaves. The insects that alight on the leaves are caught by these tentacles which bend over the insect and pour out a protein-digesting enzyme.

101. How other food substances are digested. We have learned that proteins and fats resemble starch in that they will not pass through cell membranes. Hence, these food substances, before they can pass, or diffuse, through membranes, must be digested. These changes in proteins and fats are brought about by various enzymes in plants, animals, and man. These digestive enzymes act in a manner similar to that of diastase and ptyalin. All digestive ferments are made by protoplasm (Fig. 76).

102. Why foods must be digested in order to be used within cells. Let us suppose that a cell is able to manufacture within itself all the starch, fat, and protein that it needs. This probably occurs in cells that contain chlorophyll. The question then arises — Would the cell still need to digest these food substances in order to make them available for use?

Biologists find that starch is always changed to grape sugar before it can be used in making protein or in releasing energy. Again, proteins can not be used in making living substance until they have been acted upon by digestive ferments. And, finally, fats can not be oxidized for the release of energy until they too have been digested. In other words, not only does digestion prepare food substances for passing through cell membranes, but this process is also necessary before foods can be used for any purpose within the cell itself. A single cell, then, must be capable of producing enzymes to digest each of the food substances that it uses.

103. How the human body differs from a green plant with reference to food getting and digestion. Green plants can prepare their carbohydrate food in any cell that contains chlorophyll if exposed to sunlight. Other foods may be made in any cell of the plant. To be available for use in the cell that manufactures it or in any other part of the plant, the various food substances must be digested, and every plant cell may carry on this process.

In the human body, on the other hand, all food is supplied ready-made from outside the body. Before it can enter the blood or the tissues, it must be made ready to pass through membranes. Plants like Venus's flytrap and sundew (Figs. 75, 76) also secure some of their food ready-made in the form of insects. It is necessary for them to digest these insects before they can absorb the food substances of which they are composed.

Summary

Carbohydrates must pass from leaf cells, where they are made, through the cells of stems into cells of roots, since they can not be made in the roots. *Water* and *mineral matter* must move upward through the cells of root, stem, and leaf, since these substances are necessary for food manufacture in the leaves.

Food substances are found in the various cells of the human body; therefore they must have passed from the various parts of the food canal to these cells and, in so doing, must have passed both into and out from cells.

Diffusion is the process by which the molecules of two or more gases or two or more liquids are intermingled. It is due to the inherent energy of the molecules. Only substances that form true solutions in a solvent are able to diffuse in the solvent.

A *true solution* is one in which the solute is broken up into molecules in the solvent or is broken up into such small parts that no microscope has been able to reveal their presence. Gases diffuse much more rapidly than do liquids. Substances, such as starch paste or the protein of the white of egg, may be so finely divided that they seem to form solutions in water. Such substances show little, if any, energy of diffusion but remain in suspension in water indefinitely. Substances like these are known as *colloids*.

Diffusion in living things requires that the liquids or gases pass through the membranes of cells and always through the membranes of protoplasm. *Osmosis* is the passing of liquids and dissolved substances through membranes.

A *semipermeable membrane* is one that permits the free passage of the solvent but hinders to some extent the passage of the solute. The more nearly the movement of the

solute is prevented, the more perfect is the semipermeable membrane.

Osmotic pressure is caused by the inability of the solute to pass, or diffuse, through the membrane as fast as does the solvent. Consequently the more nearly the membrane prevents the passage of the solute, the greater the osmotic pressure. Even with an imperfect semipermeable membrane the osmotic pressure may be great enough to cause the solution to rise in a thistle tube six to ten feet. Osmotic pressure partly explains the rise of sap in roots, stems, and leaves. Slices of wilted potato, when put in water, show the effect of osmotic pressure by becoming stiff and rigid.

Solvents and *their solutes* will pass through membranes. *Insoluble solids* and *semisolids in suspension* (colloids) will not diffuse through membranes. Sugar and soluble mineral matter will diffuse through membranes. Starches, fats, and insoluble minerals will not diffuse through membranes.

Insoluble food substances must be changed to *soluble substances* before they can diffuse through cell membranes.

Digestion is the changing of insoluble foods to soluble foods. *Digestive enzymes* are chemical substances made by protoplasm that bring about the digestion of starch, proteins, and fats. *Diastase* is an enzyme in plants that digests starch, and *ptyalin* is a similar enzyme found in saliva. Digestion of starch, proteins, and fats is necessary (1) that they may be made diffusible and (2) that they may be used in the cells.

REVIEW QUESTIONS

1. What leads you to think that food materials are transported through plants? Through the human body?
2. What reasons can you give for believing that food materials in some form must pass into and out from cells?
3. What is meant by diffusion of gases? By diffusion of liquids?

4. Describe an experiment to show diffusion in gases; diffusion in liquids.

5. What is a true solution? Do starch paste and white of egg form true solutions in water? Give a reason for your answer.

6. Describe an experiment to show whether starch paste, white of egg, or phosphate of lime diffuses in water.

7. What kinds of substances will diffuse in water, and what kinds will not?

8. What are the conditions under which diffusion in living things must occur?

9. Describe an experiment to show whether either water or sugar in solution will pass, or diffuse, through a membrane.

10. What food substances will pass through a membrane?

11. What is a semipermeable membrane? Why are the membranes we have used in our experiments not perfect or ideal semipermeable membranes?

12. What caused the liquids in the thistle tubes in the experiments with sugar and water and with salt and water to rise?

13. What is osmosis? What is osmotic pressure, and what causes it? What process in plants will it help to explain?

14. Will starch or protein or fat diffuse through membranes? How do you know?

15. Show why insoluble substances must be changed in living things.

16. Describe an experiment to show how a seedling makes its starch diffusible.

17. Give a description of an experiment to show how starch is made diffusible in the human body.

18. What kind of substances in plants make starch ready for diffusion? Name one of these substances and describe an experiment in which its action is shown.

19. Name several other food substances that must be digested before they become diffusible. What substances bring about this change?

20. Define digestion. State two reasons why this process is necessary in plants and in man.

CHAPTER IX

HOW WATER AND OTHER SUBSTANCES ARE ABSORBED AND DISTRIBUTED IN PLANTS

104. How we may discover the upward movement of water in plants. In the preceding chapter some reasons were given for believing that substances must move both upward and downward through any plant (**86**). If you have ever seen wilted plants revive and straighten up after the soil over the roots has been sprinkled thoroughly with water, you will have your own reason for thinking that water must enter and pass up through plants. Let us now see whether we can, by means of experiments, give visible proof that liquids pass upward through a plant. At the same time we may be able to determine whether liquids pass through all parts of the roots, stems, and leaves or whether these liquids travel most readily through certain channels.

EXERCISE 35

Through what parts of roots, stems, and leaves do liquids pass upward? Laboratory study.

Secure some well-developed bean seedlings or some weeds or any annual plant[1] with well-developed roots. Put the tips of the roots in water that has been colored with red ink or eosin powder. Leave them until the red color appears in the leaves. The red ink is used to stain the parts through which the soil water readily passes.

1. Describe what has been done, stating the kinds of materials used.
2. Split in halves lengthwise some of the roots. Through what region of the roots has the red ink passed upward?
3. Cut at various heights, both crosswise and lengthwise, sections of the stem of the bean seedling or weed.

[1] An annual plant is one that lives for one season only.

a. What evidence have you that the ink has passed up through the stem?

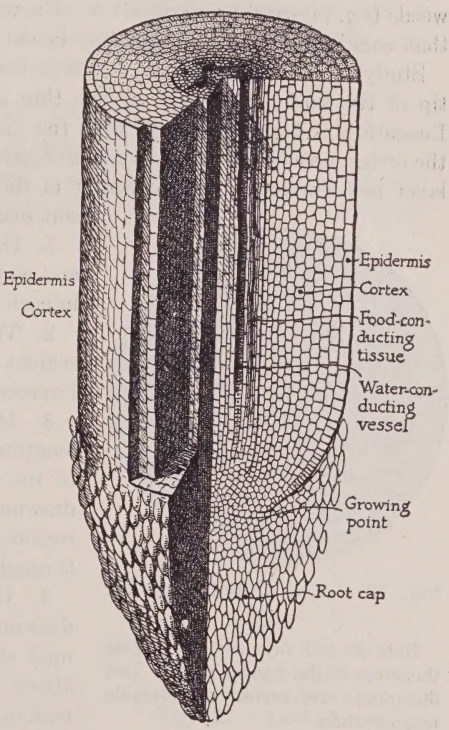
b. Through what region of the stem has the liquid passed?

4. Examine leaves that show the red color. Through what structures has the colored liquid been carried to various portions of the leaves?

EXERCISE 36

What is the general structure of roots? Laboratory study.

Select the largest roots of a well-developed bean seedling (Windsor bean, if possible) or the roots of corn or of common weeds. With the thumb and finger nail gently scrape off the outer layers from a piece of one of these roots. When no more of this material can be removed easily by this method, pick with a pin the central part of the root, which is left, so as to separate the fibers. The outer layer you have removed is largely composed of the cells of the *cortex*, and the central part that has been exposed is called the *central cylinder* (Figs. 77, 87).



From Transeau's General Botany

Fig. 77. — Structure of a root tip
The various parts are greatly magnified.

1. Tell what you have done.

2. Which is composed of the tougher and harder material, the cortex or the central cylinder?

3. Of what do you find the central cylinder to be composed?

4. Make an enlarged diagram of a lengthwise section of a piece of root to show the cortex and the central cylinder. Label each part and indicate by a label the region through which the red ink passed (Exercise 35).

EXERCISE 37

What is the general structure of annual stems? Laboratory study.

To the teacher: Cut off a sufficient number of pieces from the stems of weeds (*e.g.* pigweed or ragweed) or of a well-developed bean seedling, so that each member of the class may be supplied with a piece.

Study an annual *herbaceous* (weed or bean) stem as follows. With the tip of the knife blade peel off the thin layer known as the *epidermis*. Beneath this layer scrape off with the knife edge a green, pulpy layer, the *cortex*, until you come to a *fibrous layer*. With a pin strip the fibrous layer into threads. In the center of the stem pick out with a pin the soft material, the *pith*.

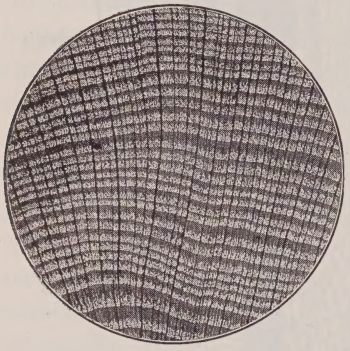


Fig. 78. — Cross section of oak wood

Note the pith rays and the varying thickness of the annual rings. This illustration represents considerable magnification.

1. Describe what you have done and state the kind of material you find in each region of an herbaceous stem.

2. Through which of these four regions does the red ink rise? (See Exercise 35.)

3. Make an enlarged drawing of a lengthwise section through the middle of the herbaceous stem. Label the drawing as a whole and each of the four regions. Indicate by a label the region through which the red ink passes.

4. If time permits make an enlarged drawing of a cross section of the annual stem and label as directed in 3 above. Indicate also by a label the region through which red ink passes.

EXERCISE 38

What is the structure of a woody stem? Laboratory study.

Study the *woody stem* as follows. By means of the thumb nail remove the layers of *bark*. Tear apart with a pin the tough *woody layer* and notice that it is composed of fibers. Pick out from the center of the stem the soft *pith*.

1. Describe what you have done and state the kind of material you find in each layer of the woody stem.

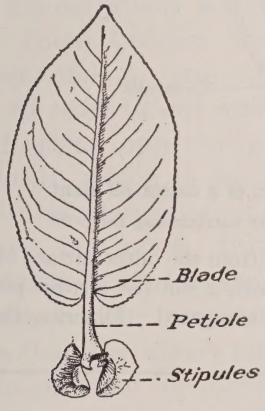
2. Examine a cross section of a portion of a woody stem the lower end of which has stood in red ink. Through which of these regions does the red ink rise?

3. Make an enlarged drawing of a lengthwise section through the middle of the woody stem. Label the drawing as a whole and each of the three regions. Indicate by a label the region of the woody stem through which the red ink passes upward.

EXERCISE 39

What is the general structure of leaves? Laboratory study.

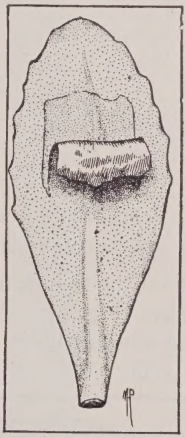
1. Examine a leaf from a weed, a bean seedling, or a tree and note that it is made up of the following parts: *a leafstalk,* which attaches the leaf to the stem of the plant, and a broader portion called the *blade.* Note the course of the main veins. Make a drawing (natural size) by tracing the outline of the leafstalk and the blade. Draw carefully the main veins and a few of their branches, being careful to show their relative size and connections. Label the leafstalk, blade, main veins, network



From Gager's Fundamentals of Botany

Fig. 79. — Leaf of a willow

Note the petiole, or leafstalk, with the two appendages called stipules.



From Gager's Fundamentals of Botany

Fig. 80. — Leaf of live-forever

The illustration shows the epidermis in process of being peeled off.

of veins, and the part of the leaf through which red ink passes. State the kind of leaf that you have drawn.

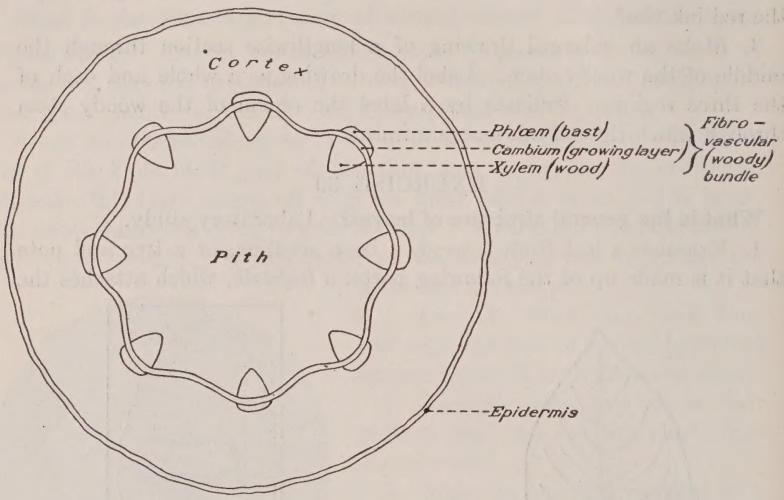


Fig. 81. — Section of the stem of a castor-oil plant
Note the sheath of woody bundles surrounding the pith.

2. Peel off the thin skin, or *epidermis*, from the outer surface of a large vein of a leaf (Fig. 80). Pick to pieces with a pin the central portion of a vein and note the fibers of which it is composed. Describe the structure of a vein.

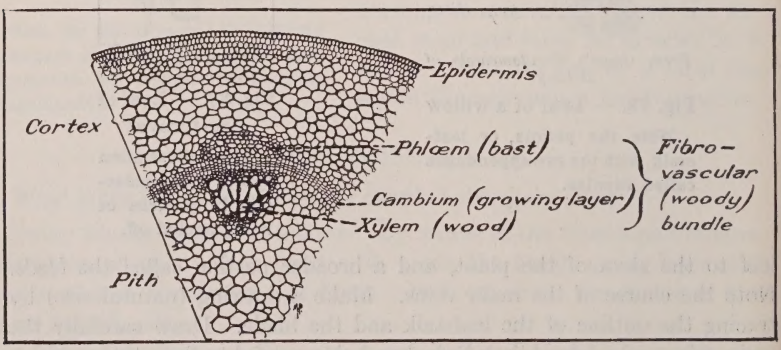
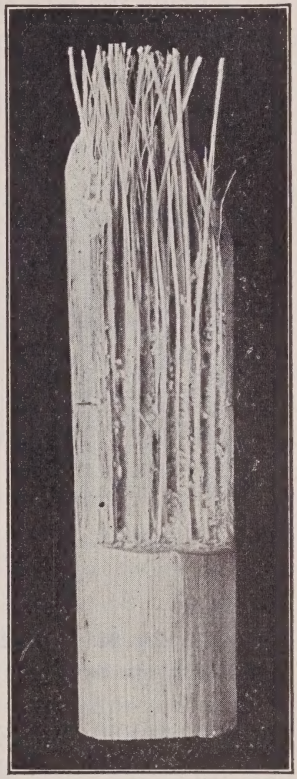


Fig. 82. — Structure of the stem of a castor-oil plant
Note the woody bundle with the cells that surround it.

105. How roots, stems, and leaves are fitted for carrying soil water. In all three of these organs of plants we have demonstrated the presence of fibrous material, which we have torn apart into threads. In the roots these fibers are found in the central cylinder (Fig. 77). In *young* herbaceous stems the fibrous material is arranged in the form of a sheath of woody bundles that surround the pith (Fig. 81). In *older* annual stems and in woody stems these bundles increase in number and in size until they come so close to one another that they form an apparently continuous sheath, which in woody stems constitutes a large part of the stem. Finally, in leaves this fibrous material is limited to the leafstalk and veins. Our dissections have shown that the woody bundles are continuous from the roots, through the stem, out into the veins of the leaves (Fig. 79), and our experiment with the red ink proves that this same material contains the passageways through which liquids readily pass upward.



From Gager's Fundamentals of Botany

Fig. 83. — Cornstalk

The cut-away section shows the threads, which are woody bundles. Irregular masses of pith can be seen between the woody bundles.

A different arrangement of woody bundles is shown in a stem like the cornstalk (Fig. 83) or bamboo. Such a stem is covered on the outside with a hardened *rind*, within

which is the *pith*. The woody bundles are scattered through the pith instead of being arranged in a sheath of bundles just outside the pith as in the young woody stem.

Let us now see why sap travels upward through the fibrous regions and not through other parts of the plant. In order to understand this, we need to know something of

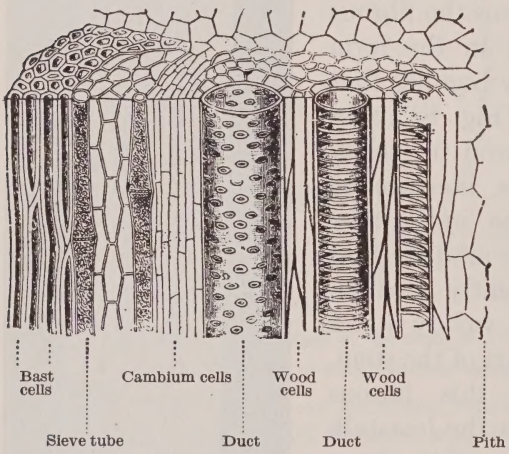


Fig. 84. — Woody bundle
Lengthwise section of a sunflower stem.

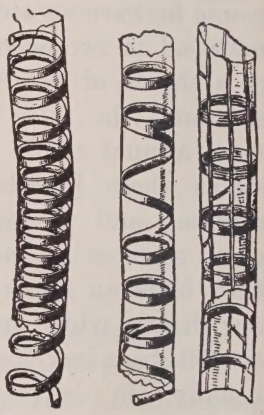


Fig. 85. — Separate ducts
The walls of these pipes are strengthened by spiral fibers or rings.

its microscopic structure. On examining a thin lengthwise section of these woody bundles in root, stem, or leaf, we find scattered among other cells tiny tubes, or *ducts*, which are empty except when they are carrying *sap* (Fig. 84). It is easier to make out these ducts when they are separated from each other as shown in Fig. 85. Then we see that the walls of the ducts are frequently thickened and therefore strengthened by spiral threads or by rings.

Running parallel to and between these ducts are elongated, more or less sliver-shaped, *wood cells*, which have

thick walls. These overlap each other at the ends and give toughness to the woody bundles wherever these are found. Since the ducts are seen only in fibrous material, it is evident that they furnish a ready means by which the soil water with its mineral matter passes upward through the plant.

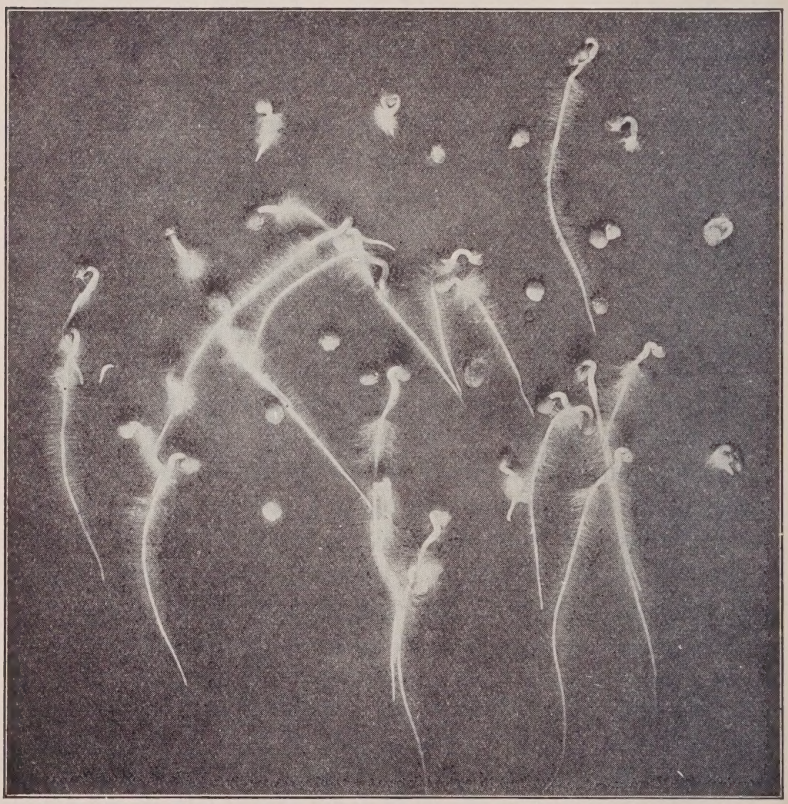
106. How roots are fitted to absorb soil water. You will remember that the outside layer of the root consists of soft material that is readily scraped off. It is evident that soil water must pass through this layer in order to enter the ducts in the central cylinder. One may readily surmise that the soil water enters the thin-walled cells on the outside of the root, and this surmise is correct. But since some of these cells are specially fitted for this process of absorption, we need to study this root structure somewhat more in detail.

If we examine the roots of young seedlings that have germinated on moist blotting paper in a Petri dish (Fig. 86), we find that the roots are covered with thousands of tiny outgrowths called *root hairs* [1] (Fig. 87). When a thin lengthwise section of such a root is looked at with a compound microscope, each root hair is found to be an outgrowth of certain cells found in a single layer of thin-walled cells covering the cortex (Fig. 88). This single layer is the *epidermis* of the root. Most of the soil water enters through these root hairs, and we are now to see how they are adapted for this purpose.

Inside the thin cell wall of each root hair (Fig. 88) is a lining of protoplasm, and the rest of the root hair is filled with *cell sap*, which contains minerals and perhaps sugar in solution. Root hairs especially lend themselves to the process of osmosis, since we have here two liquids; namely,

[1] Root hairs should be prepared for class demonstration as described in Appendix II.

soil water, which is a very weak solution of mineral matter, and the cell sap, a much denser solution. These two liquids



From Gager's Fundamentals of Botany

Fig. 86. — Sprouting mustard seeds

The seeds are growing on moist blotting paper. Note the abundance of root hairs.

are separated by a semipermeable membrane consisting of the cell wall with its protoplasmic lining.

From our experiments in Chapter VIII with nonliving membranes we should expect to find that the solvent soil

water would enter the root hairs more readily and that the solutes in the cell sap would pass out to a lesser degree. Biologists have shown, however, that in reality, practically only the inward movement of soil water occurs. The outward flow of the solutes is prevented by the layer of protoplasm, which acts as a nearly perfect semipermeable membrane. Thus we see that protoplasm forms a membrane that has a selective function.

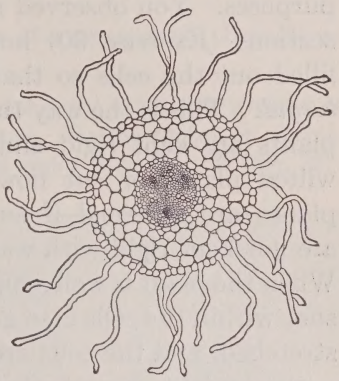


Fig. 87. — Cross section of a root
Note the ducts in the central cylinder and the root hairs on the outside.

By a similar osmotic action the soil water with a very small percentage of mineral matter passes inward from one cell of the cortex to another until it reaches the ducts of the central cylinder, through which the sap is distributed throughout the plant (Fig's. 85, 87).

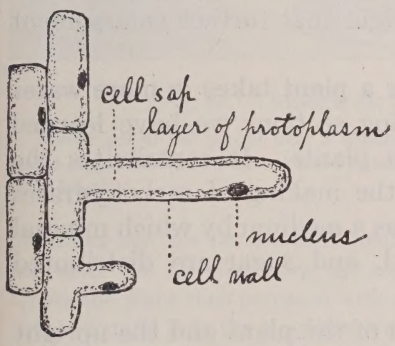


Fig. 88. — Two root hairs
This illustration represents highly magnified sections.

107. How osmosis and osmotic pressure are useful to plants. Much of the interchange of soluble materials between cells in both plants and animals is due to osmosis. This process quite largely accounts for the absorption of soil water by the root hairs and roots of plants. Doubtless it partly accounts for the upward movement of sap through the roots, stems, and leaves.

But in plants at least osmotic pressure serves other useful purposes. You observed in the experiment with the potato sections (Exercise 30) how the inward flow of the water filled out the cells so that the whole section was rigid, or *turgid*. This is the way that stems and leaves of herbaceous plants are kept rigid and erect. Everyone has noted that wilted plants or cut flowers are revived and that celery plants are stiffened if supplied with water. If the cells are not kept rigid with water, the plant soon wilts and dies. When the plant is well supplied with water, the osmotic pressure within the cells is so great that the cell walls are thereby stretched, and the cells are made larger.

One might expect that this stretching process would cause the cell walls to break. This does sometimes occur, but usually the cells keep the walls intact by gradually adding more cellulose as the walls become thinner. The *growth* of plants, therefore, is also dependent on osmosis and osmotic pressure. Without this pressure in young cells the walls would soon become so rigid that further enlargement would be impossible.

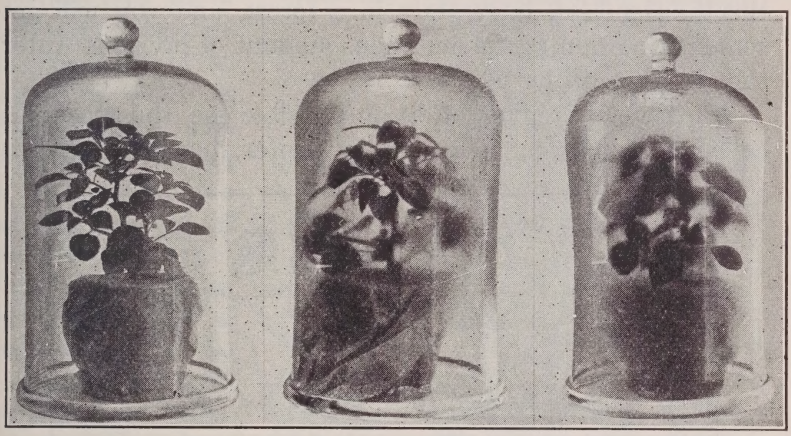
108. To determine whether a plant takes in more water than it can use. In preceding sections we have learned that water has many uses in plants. It contributes the greater bulk of material for the making of carbohydrates and protoplasm, and it serves as a medium by which mineral matter, oxygen, carbon dioxid, and sugar are distributed through the plant.

Nor is this all. The growth of the plant and the upright condition of the leaves and young stems are also dependent on water. Would you expect a plant to take in more of this material than it needed for all these purposes? The following experiment will make plain the answer to this question.

EXERCISE 40

Is water vapor given off by the leaves of a green plant? Laboratory study.

Wrap sheet rubber or thin oilcloth about a pot containing a vigorous plant after it has been thoroughly watered. Tie the rubber or oilcloth about the stem to prevent the escape of water from the soil (Fig. 89).



From Gager's Fundamentals of Botany

Fig. 89. — Experiment to illustrate transpiration

Flower pot at left placed near a window and beneath a bell jar; middle picture, same experiment at the end of three hours; picture at right, same plant after twenty-four hours.

If rubber can not be obtained, melted paraffin may be poured over the soil after the pot has been painted inside and out with hot paraffin. Cover the plant thus prepared with a large bell jar with the inner surface dry and stand it in the sun for a few hours.

1. Describe the preparation of the experiment, stating the reason for the use of the rubber or paraffin.
2. State your observations and conclusion.
3. Why is the bell jar necessary?
4. What becomes of the water vapor given off by the leaves of trees and of other plants?

109. What transpiration is and how it can be measured. In the preceding experiment we saw that even a small plant gives off, or *excretes*, a considerable quantity of water. If we were to weigh the plant at the beginning and then at intervals, we might determine the exact amount of water given off each day. It has been estimated that large trees give off as much as 180 gallons daily. Multiply this by the thousands of large trees in a forest, and you will get some conception of the enormous amount of invisible water that is given off by plants.

When water is given off as an invisible gas, the process is called *transpiration*. Not all the water, however, that is

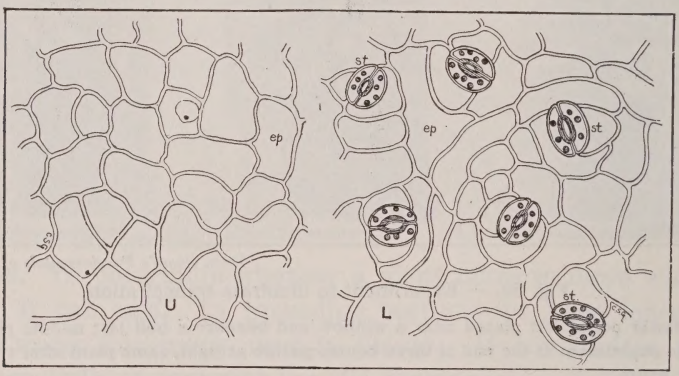


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Fig. 90. — Epidermis of leaf of lizard's-tail
U, upper epidermis; L, lower epidermis; st, guard cells of stomata. Compare with Fig. 91.

given off by plants is transpired. Under special conditions it may actually ooze out of the ends of the veins in tiny drops of water, as in the leaves of grape and young nasturtium plants.

110. How leaves are fitted to allow the escape of water vapor. To understand how leaves are adapted for transpiration, we shall

need to examine the structure of a leaf under the microscope. Strip off some of the epidermis of a hyacinth or other thick leaf, lay the epidermis on a glass slide, add a drop of water, and cover with a cover glass. Examine this specimen with the low power of the compound microscope. You will see cells somewhat similar to those shown in Fig. 90.

These cells are of two sorts: There are the larger cells of the epidermis, which fit closely together, and, scattered among these cells, are smaller, oval-shaped or circular structures, each of which has a tiny hole or narrow slit in the center. On more careful examination it will be found that each oval body is really made up of two cells hollowed out on their inner surfaces in such a way as to leave an opening between them. The two cells are known as *guard cells*, and the passage between them is called a *stoma* (plural, *stomata*, from Greek, meaning *mouth*) (Fig. 90). The illustration of a cross section of a leaf shows the arrangement of the guard cells and the passageway, or stoma, leading into a cavity within the leaf, known as an *air space*. The air spaces are cavities between the cells (Fig. 91).

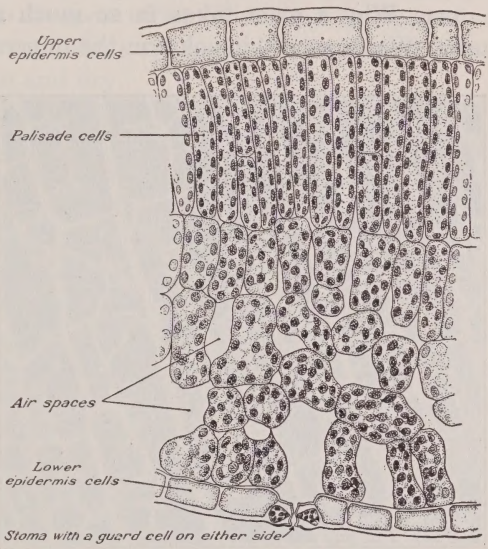


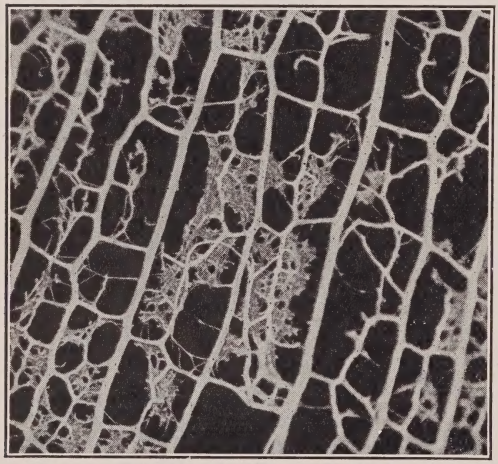
Fig. 91. — Section of leaf

This illustration represents a highly magnified section. Note the chlorophyll grains in the cells inside the leaf and in the guard cells.

It will now be possible to imagine how the transpiration of

water from the leaf occurs. As we have shown, water from the soil is continually moving up through the ducts in the roots, stems, and leaves. Finally it comes into the cells surrounding the air spaces. The water must then pass through the thin walls of these cells into the air spaces. From the air spaces it may diffuse through the stomata into the outer air.

111. Why a plant takes in so much more water than it can use. Water carries in solution the minerals needed by the plant. But soil water contains only a small percentage of mineral matter; therefore, a greater volume of water than is necessary for other purposes must pass through the plant in order to furnish the required amount of minerals.



From Gager's Fundamentals of Botany

Fig. 92. — Veins in the leaf of the rubber plant
The section of the leaf was photographed through a microscope.

One of the principal uses of the stomata is to afford a constant supply of carbon dioxid to the cells that contain chlorophyll. Since carbon dioxid will be needed for starch manufacture in the daytime, the stomata must be open at a time when there would naturally be the greatest amount of evaporation or transpiration due to the heat of the sun. For this reason many scientists maintain that transpiration can not be prevented, since the stomata must be open to permit the entrance of plenty of carbon dioxid. If this is the true explanation of transpiration, it seems that there would be developed some means for checking transpira-

tion, provided photosynthesis is not interfered with. Such means are present, as we shall now see.

112. How guard cells help to check transpiration. When the cells of the plant are fully distended (turgid) with water, the guard cells are likely to be in the same condition. This results in so changing the shape of the guard cells that the passageway, or stoma, between them is open wide. Therefore transpiration can go on readily if the conditions are favorable for evaporation, that is, if the air is warm and dry.

If, however, the air has nearly all the moisture it can hold, little transpiration can occur, no matter how widely open the stomata may be. Therefore plants will not wilt on very muggy days, even if the temperature is high. If, on the other hand, the plant cells, including the guard cells, are not well filled, the walls of the guard cells tend to come together, thus more or less closing the stomata and, to a certain extent, prevent the escape of moisture. However, this will not always stop transpiration sufficiently to prevent wilting. In fact, transpiration may go on until the plant droops. This, as we have stated, is very likely to occur in bright sunlight, for then the guard cells can not close,[1] even though other cells may have lost enough water to cause wilting. Hence we see that the guard cells are not altogether adapted to control transpiration.

113. How leaves, stems, and roots are adapted for carrying manufactured foods downward. Carbohydrate manufacture is carried on wholly in the green parts of leaves and stems and these materials must find their way to other parts of the plant (*e.g.* places of storage in fruits, seeds, stems, or roots). Through what channels does this movement of food materials take place? When we examine still further one of the fibrous bundles described in **105,** we

[1] The guard cells can not close because they will be distended with water. This is due to the fact that in the sunlight the guard cells will be making sugar. The sugar increases the osmotic pressure in these cells, thus drawing in water and distending them and keeping the stomata open.

shall find its outer region contains tubular cells somewhat different in appearance from the ducts already described.

Fig. 93. — A sieve tube

A, lengthwise section, showing edge view of sieve plate; *B*, surface view of sieve plate. Note the perforations.

These tubes are called *sieve tubes* because perforated cross partitions, which remind one of a sieve or a strainer (Fig. 93), appear at intervals along their course. Like ducts, these sieve tubes form a continuous system, beginning in the tiny veins of the leaves and extending downward through stem and root. It is through these tubes that food materials travel from their place of manufacture to regions of food storage. Sieve tubes, unlike ducts, contain a thin layer of protoplasm. When one strips off the bark of a woody stem, one finds its inner layer consists of white fibers, and it is in this layer of bark that sieve tubes are found. It is relatively easy to show that this region of bark is concerned with the downward movement of sap, for, when a wire is tightly bound around a twig or a tree trunk, a swelling, which is found to contain considerable supplies of manufactured food, appears in the bark above the wire. If a ring of this fibrous bark is cut from around a tree trunk, the whole tree dies during the second year as a result of this *girdling process*, since the lower parts of the tree are cut off from their food supply.

Summary

A *young root* has a *central cylinder* composed of *ducts* and *wood cells*, a *cortex* composed of several layers of thin-walled cells, and an *epidermis* consisting of a single layer of thin-walled cells, many of which form *root hairs* near the tip end of the young root.

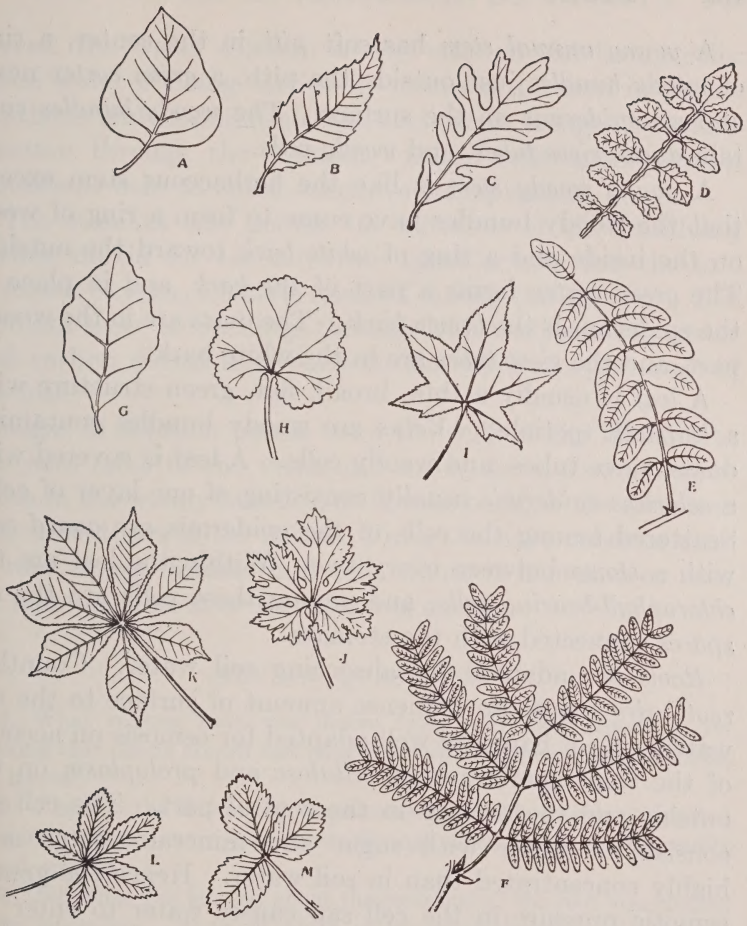


Fig. 94. — Forms of leaves

Simple leaves

A, lilac	**C, white oak**	**G, oak**	**I, sweet gum**
B, chestnut	**D, celandine**	**H, geranium**	**J, buttercup**

Compound leaves

E, locust	**L, cinquefoil;**	**F, wild tamarind**
K, horse chestnut	**M, wild strawberry**	**(twice compound)**

A *young annual stem* has soft *pith* in the center, a ring of *woody bundles* just outside the pith, a *green cortex* next, and an *epidermis* on the surface. The *woody bundles* contain *ducts*, *sieve tubes*, and *woody cells*.

A *young woody stem* is like the herbaceous stem except that the woody bundles have come to form a ring of wood on the inside and a ring of *white bark* toward the outside. The *green cortex* forms a part of the *bark*, and in place of the epidermis is the *brown bark*. The *ducts* are in the woody part, and the *sieve tubes* are in the white bark.

A *leaf* is usually a thin, broad, flat, green structure with a *leafstalk* (petiole). *Veins* are woody bundles containing ducts, sieve tubes, and woody cells. A leaf is covered with a *colorless epidermis* usually consisting of one layer of cells. Scattered among the cells of the epidermis are *guard cells* with a *stoma* between every two. Within the leaf are the *chlorophyll-bearing cells*, and among these cells are the *air spaces* connected with the stomata.

Roots are adapted for absorbing soil water. Countless *root hairs* expose an immense amount of surface to the soil water. Root hairs are well adapted for osmosis on account of the thin membranes of *cellulose* and *protoplasm* on the outside and the *cell sap* in the central part. The cell sap consists of water with sugar and mineral solutes more highly concentrated than in soil water. Hence the greater osmotic pressure in the cell sap causes water to enter the root hairs through the cell membranes, which prevent the outward flow of sugar and mineral solutes. Water with a very small percentage of mineral solutes now passes on through the *cortical cells* and so into the *ducts* of the *central cylinder*.

The *ducts* of the *woody bundles* of the *stem* receive the soil water from the ducts of the root and pass it on to the ducts of the veins of the leaves. From the ducts of the stem and

leaves, the water diffuses slowly into all the living cells. More water is being carried up than can be used in photosynthesis and assimilation, and this excess escapes by transpiration through the stomata. *Guard cells* under certain conditions help to check excessive transpiration.

The stomata also permit the entrance of air containing carbon dioxid for carbohydrate manufacture and the exit of excess oxygen, which is released during this process. The stomata serve as openings through which oxygen may enter and carbon dioxid may leave in the respiratory process of the leaf.

Sugar in solution passes from the cells of the leaves into the *sieve tubes* in the veins and so on down through sieve tubes in the woody bundles, or fibrous bark, of the stem and into sieve tubes in the roots. From the sieve tubes of stem or root, sugar diffuses into cells where it is stored or used for making protein or for releasing energy.

REVIEW QUESTIONS

1. What reasons have you drawn from your own experience for thinking that plants absorb and pass water upward through roots, stems, and leaves?

2. Describe the laboratory experiment by which was demonstrated the parts of roots, stems, and leaves through which red ink most readily passed upward.

3. Tell what you learned about the structure of the root you studied in the laboratory. Through which of the parts described did the red ink pass?

4. Describe your experiment with the stem of the weed or bean plant, telling what you found out about its structure and giving the names of the parts.

5. Through which parts of the annual stem did the red ink pass upward?

6. Name and describe the parts of the leaf you studied. Through which part of the leaf did the red ink pass?

7. What did you find out about the structure of the veins?

8. In what respects are the parts of roots, stems, and leaves through which red ink passed upward alike?

9. How does the arrangement of woody bundles in a corn stem differ from that in the annual stems studied?

10. What are ducts like, where in plants are they found, and what useful purpose do they serve?

11. Where are wood cells found in plants? How do wood cells differ from ducts in structure and function?

12. Through which layer of a root must soil water enter, and by what process?

13. State what you have learned about root hairs as to their location, number, and shape.

14. Describe the microscopic structure of a root hair.

15. Show how a root hair is well adapted for the process of osmosis.

16. Do root hairs lose to the soil their sugar and minerals? Explain.

17. How is a young root well adapted in all respects for absorption of water?

18. Describe and explain the ways in which osmosis and osmotic pressure are useful to plants.

19. Describe an experiment which shows that a plant takes in more water than it uses.

20. State five uses of water to plants.

21. State the amount of water said to be transpired by a large tree.

22. In what ways besides transpiration may water be given off from leaves?

23. How are leaves and stems adapted for carrying foods downward?

24. Why does the girdling process kill a tree the second year and not the first?

25. How do sieve tubes differ from ducts in structure and function?

CHAPTER X

HOW THE HUMAN BODY IS FITTED FOR THE DIGESTION OF FOODS

114. Where digestion takes place in the human body. The carbohydrates, proteins, and most of the fats needed by our bodies to furnish material for repair or growth and for our various activities are supplied from the plant or animal foods that we eat. Our foods are taken into our bodies through the mouth opening and pass down through a rather complicated tube, the *alimentary canal.* So long as it remains within this tube, food is not available for use by the brain, muscles, or other organs of the body, for none of these food substances with the possible exception of some of the sugars and some of the minerals is diffusible. Hence, they must be digested before they can pass through the cell membranes and enter the blood or any of the working tissues. We are now to study the organs of the body, known as the *digestive organs,* in which foods are prepared for diffusion and for use by the cells.

115. Of what parts the alimentary canal consists. In order of their occurrence, the alimentary canal (Fig. 97) consists of the following parts: mouth cavity, throat cavity, gullet, stomach, small intestine, and large intestine. Let us now consider these various regions more in detail. In reality the alimentary canal begins at the *mouth opening,* which is enlarged to form the *mouth cavity.* The mouth cavity narrows at the back considerably and thus communicates with the *throat cavity* (Fig. 99). Below the

throat cavity the alimentary canal continues as a tube of rather small diameter, the *gullet*, which conducts the food downward through the neck region and through that part

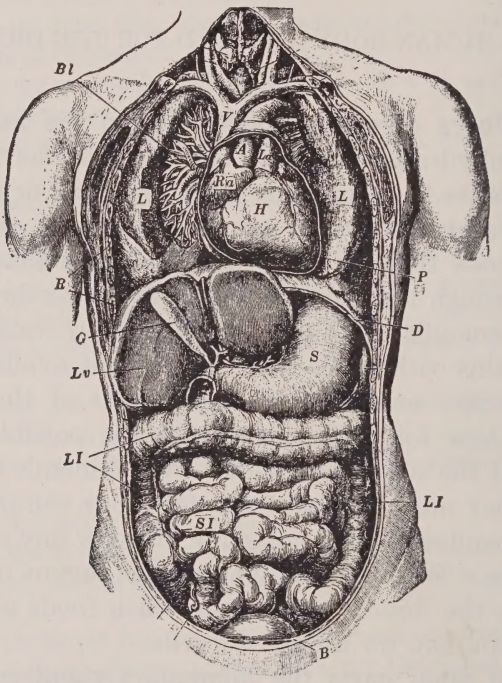


Fig. 95. — Organs of chest and abdomen

A, aorta (main artery); *B*, bladder; *Bl*, bronchial tubes; *D*, diaphragm; *G*, gall bladder; *H*, heart; *L*, lungs; *La*, pulmonary artery; *LI*, large intestine; *Lv*, liver; *P*, pericardium; *R*, ribs; *Ra*, right auricle; *S*, stomach; *SI*, small intestine; *V*, main veins. (From Schilling.)

of the body containing the heart and lungs, called the chest cavity. After passing through a muscular partition known as the diaphragm, the gullet enters the lower cavity of the trunk, called the abdomen, or abdominal cavity. Here the food tube becomes greatly enlarged to form a pouch,

the *stomach*. From the stomach the food is forced through a long, much-coiled tube called the *small intestine*, which occupies a large part of the abdominal cavity. Finally,

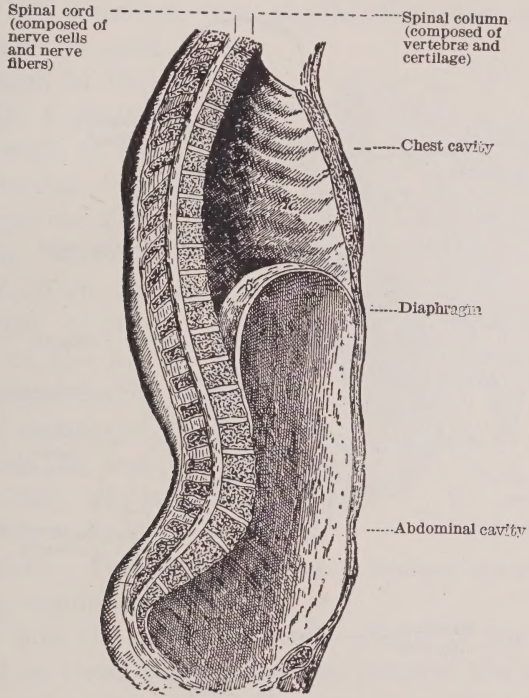

Spinal cord (composed of nerve cells and nerve fibers)
Spinal column (composed of vertebræ and certilage)
Chest cavity
Diaphragm
Abdominal cavity

Fig. 96. — Section of the human body

Note the dome-shaped diaphragm which separates the chest cavity from the abdominal cavity.

what remains of the food we have eaten enters a somewhat larger part of the tube, the *large intestine*, which communicates through an opening with the exterior. Hence, it is evident that so long as the food remains within the alimentary canal, it is not in any real sense a part of the body.

116. What the digestive glands are. We know that, if nondiffusible foods are to be made diffusible and also ready for use, digestive ferments, or enzymes, are necessary. In

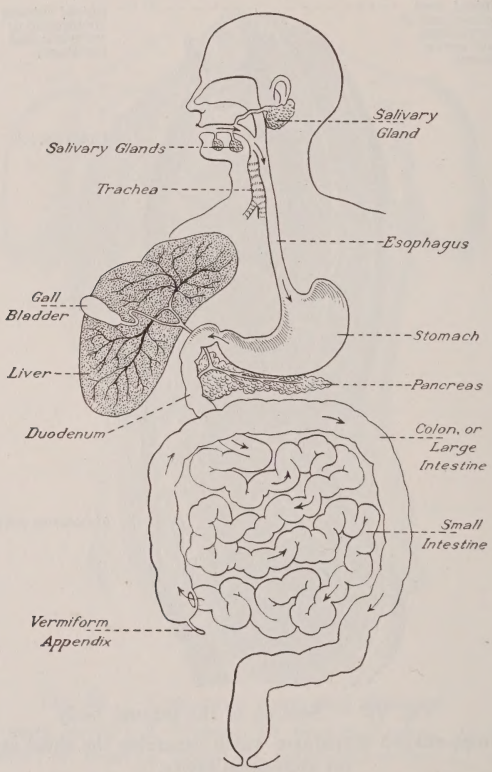


Fig. 97. — Parts of the alimentary canal

our bodies these are supplied by special organs, the *digestive glands*, which consist of masses of special cells found either in the walls of the digestive tube or lying outside this tube. In either case the digestive juices containing the ferments formed in these gland cells enter the mouth cavity, the

stomach, or the small intestine through longer or shorter pipes, or *ducts* (Fig. 98).

The glands that furnish the saliva to the mouth cavity are known as the *salivary glands*. In the walls of the stomach are countless tiny glands that form the *gastric juice*, which is used for digestion in that organ. In a similar way the walls of the small intestine supply a digestive fluid called the *intestinal juice*. And in the abdominal cavity outside of the alimentary canal are the *liver* and *pancreas*, two glands of considerable size, which give out *bile* and *pancreatic juice*. These fluids are conducted by ducts into the small intestine. Some of the ferments contained in these digestive juices prepare the starch for diffusion, as we proved in the case of saliva; others act upon proteins; and still others make fats diffusible. Water and certain sugars and mineral matter that will dissolve in water need no preparation to make them available for diffusion and use in the body.

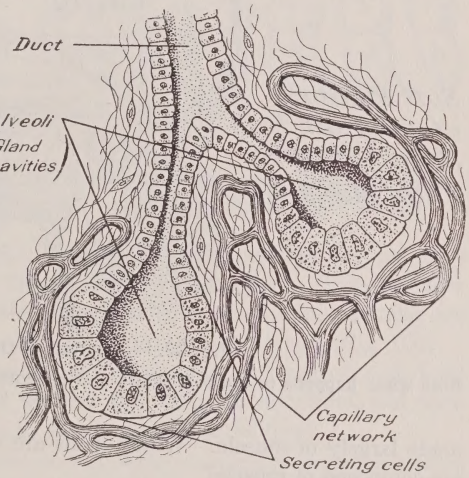


Fig. 98. — Structure of a gland

EXERCISE 41

What is the action of the cheeks and the tongue in chewing and in swallowing food? Home work.

1. Press your forefinger against the roof of the mouth, the side walls

outside the teeth (cheeks), and the floor of the mouth cavity. The walls that are rigid are composed largely of bone; those that are yielding are

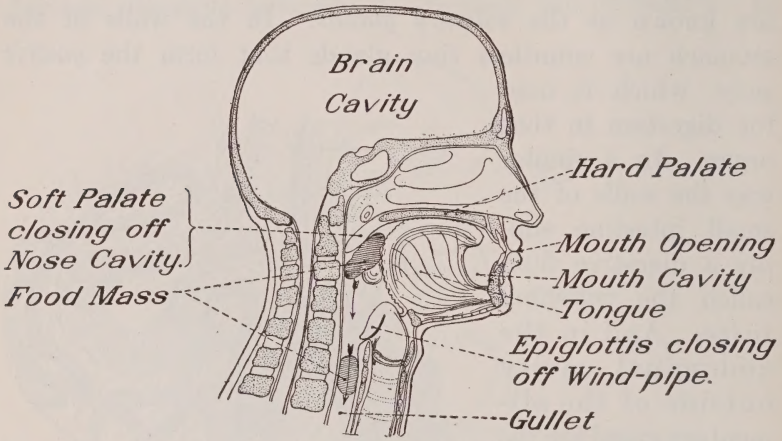


Fig. 99. — Section of the head

Note what happens to the soft palate and epiglottis when food is being swallowed.

made largely of muscle. Which walls are composed of bone and which are composed of muscle?

2. To what part of the mouth cavity is the tongue attached? Which end of the tongue is free?

3. While chewing a piece of solid food, observe and then explain how the tongue and cheeks act to keep food between the teeth.

4. Repeat a number of times the act of swallowing some solid food. Explain how the tongue acts in forcing food into the throat (Fig. 99).

EXERCISE 42

A study of the teeth. Home work.

A. How are the teeth adapted for biting and chewing food?

1. Bite off a piece of apple or bread and describe the action of the lower jaw in this process.

2. In what part of each jaw are found the teeth that are used in biting off pieces of food? These teeth are known as *incisors*.

3. Describe the cutting edge of one of the incisors.

4. Thoroughly chew a piece of bread or meat and observe and then describe the action of the lower jaw during this process.

5. In what part of each jaw are found the teeth that are used in grinding food? The grinding teeth are known as *molars*.

6. Examine one of the molars with the aid of a mirror and describe its grinding surface.

B. To determine the number and kinds of teeth (Fig. 100) in one's mouth and also to find out in what condition the teeth are.

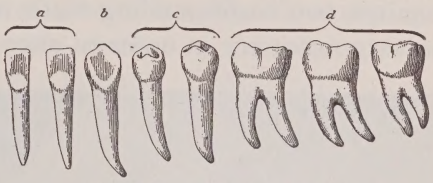


Fig. 100. — Kinds of teeth

***a*, incisors; *b*, canine; *c*, bicuspids or premolars; *d*, molars; tooth at right, wisdom tooth.**

1. NOTE (to be copied). There are two kinds of cutting, or biting, teeth, the *incisors* (from the Latin, meaning *to cut into*) and the *canines* (from the Latin, meaning *dog*, so called because they often resemble the pointed teeth of a dog). There are also two kinds of grinding teeth, the *bicuspids* (from the Latin, meaning *two points*) and the *molars* (from the Latin, meaning *millstone*)[1] (Fig. 100).

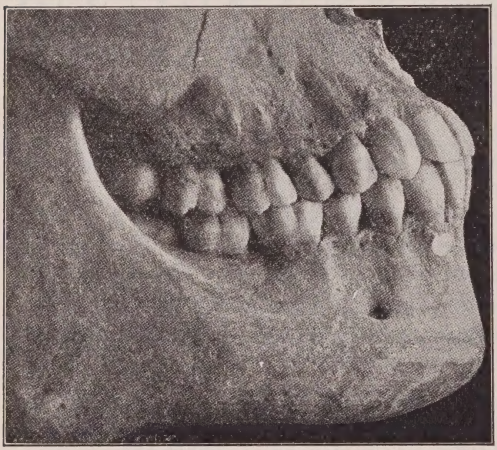
2. Use a hand mirror to determine the number of teeth of each kind that you have, the number of cavities and fillings in each kind, and then record the numbers in a table in your notebook as follows:

	Upper Jaw						Lower Jaw					
	Right Half			Left Half			Right Half			Left Half		
	Number of			*Number of*			*Number of*			*Number of*		
	Teeth	*Cavities*	*Fillings*	*Teeth*	*Cavities*	*Fillings*	*Teeth*	*Cavities*	*Fillings*	*Teeth*	*Cavities*	*Fillings*
Incisors .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Canines .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bicuspids .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Molars .	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

117. How the teeth are placed. Within the mouth cavity the solid food is cut into small pieces, mixed with

[1] Human teeth may be obtained from a dentist. They should be cleaned by being boiled in strong caustic soda solution and then in water. If possible, each student should examine and make a drawing of one of each of the kinds of teeth named above.

the juices of the mouth, and then ground into a pulpy mass. A large part of this work is done by the teeth, which are set in two semicircular arches (Fig. 101). In a normal set of teeth each grinding tooth in the lower jaw works against two corresponding teeth in the upper jaw, and this is very necessary in order to chew the food properly and to keep the teeth and gums in a healthy condition. If, however, the teeth have not developed as shown in Fig. 101, a competent dentist should be consulted and his advice followed.



From Angle's Malocclusion of the Teeth

Fig. 101. — Proper arrangement of the teeth while chewing

Note that each tooth of the lower jaw works against two teeth of the upper jaw.

118. What is meant by the temporary and the permanent teeth. During early childhood there appears a first set of *temporary*, or *milk teeth*, which later are loosened and displaced by the growth of the *permanent set* (Fig. 101). There are but twenty teeth in the milk set instead of the thirty-two of the permanent set. The milk teeth appear gradually, the lower incisors usually being the first to push through the gums at about the sixth month. The third permanent molars of each half-jaw often appear as late as the twentieth year; they are known as the *wisdom teeth*. Unfortunately many people think that cavities in the temporary teeth need not

be filled. If these teeth are allowed to decay early, the permanent teeth are likely to appear before the jaw has grown sufficiently, and irregularities in the permanent set will be the result.

119. What the structure of a tooth is. The three regions of a tooth (Fig. 102) are the *crown*, or the portion that extends beyond the gums, the *neck*, which is covered by the gums, and the *root* or *roots*, which are imbedded in the upper or lower jawbone. The materials of which a tooth is composed are well shown in a vertical section in Fig. 102. The crown is covered with a layer of *enamel*, which is the hardest substance in the body and likewise very brittle. This enamel is thickest over the biting or grinding surface, gradually becoming thinner down the exposed sides, and disappearing altogether in the neck region of the tooth. In this region begins the bony *cement*, which completely encloses the roots and fastens the tooth to the jawbone. Within the enamel and the cement is the bony *dentine*, and this forms the greater part of the tooth. In the central part is the *pulp cavity*. This region is supplied with nerves and blood vessels, which enter through a small opening at the end of each root. The blood furnishes the teeth with new building material.

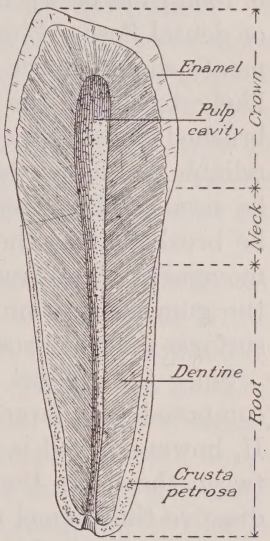


Fig. 102. — Structure of a tooth

Crusta petrosa is another name for the cement of a tooth.

120. How the teeth should be cared for. Too much stress can not be laid on the importance of caring for

the teeth since decaying teeth are frequently painful, are always unsightly, are usually the cause of ill-smelling breath, and often lead to indigestion, rheumatism, and even worse ills. *Teeth should be cleaned* at least on rising in the morning and before going to bed. One should remove any bits of food from between the teeth by using a wooden toothpick or dental floss. Pins, knife blades, or other metallic implements should never be used for this purpose, for they are likely to injure the brittle enamel. The teeth should be brushed thoroughly on all sides, and warm water and a reliable tooth powder or a little pure Castile soap should be used. The inner and outer sides of the teeth should be brushed from the gums toward the crown in a circular movement away from the gums in order to avoid pushing the gum away from the neck of the tooth. The grinding surfaces may be brushed in any direction.

Since the enamel that covers the crown of the tooth is composed very largely of mineral matter, it can not decay. If, however, food is allowed to decompose in the spaces between the teeth, the acids formed by decay (199) gradually dissolve the enamel until a cavity is formed. When the dentine is reached, this part of the tooth rapidly decays, since it contains living matter. Hence, it is most important to keep the enamel intact and polished.

The teeth ought never to be used to crack nuts or to bite hard substances, for, while the enamel is a very hard substance, it is also brittle and may be cracked or broken off by such treatment. If once lost, it will not grow again. It is evident, therefore, that it is very essential to protect this outer layer from the action of acids and from mechanical injuries.

Some people seem to think that the loss of natural teeth is not a very serious matter and that false teeth are just

as effective as those teeth that are provided by nature. Experiments have shown, however, that the power to crush food with false teeth is only about one fifth that of the power exerted by a normal set of teeth. Hence, loss of teeth is very likely to result in imperfect chewing of food, with consequent ill-health resulting from indigestion. If one has been unfortunate enough to have lost one or more teeth, the gaps should be promptly filled by bridge work or removable plates. The teeth should be examined by a dentist *at least twice a year* so that cavities found may be promptly filled. In short, everything possible should be done to secure and preserve a beautiful and effective set of teeth.

121. Why exercising the teeth is important. We are all more or less familiar with the fact that all the organs of the body require exercise to keep them in a vigorous condition. While we know that this is true with regard to the muscles of our arms and legs, we forget that our teeth are organs which also require proper exercise to keep them well nourished and in a healthy state. To this end it is necessary that much of the food that one eats should be of such a nature as to require thorough chewing. The teeth are supplied with blood vessels and when the teeth are used in biting or chewing the blood is sent to these blood vessels in greater quantity than at other times. Too much of our food is so soft that no chewing is required before swallowing.

The right kind of a diet is also of great importance in keeping the teeth from decay. No matter how carefully one may clean the teeth, decay can not be prevented unless the diet is of such a nature as to supply all the substances needed to keep the whole body in a vigorous state of health.

122. How the alimentary canal is fitted to carry on its functions. The general structure of any part of the food

tube will be made clear if we study a generalized diagram of a section (Fig. 103), which with modifications will apply to the walls of the throat, gullet, stomach, and intestine. In the first place, the whole tube is lined with a thin covering of cells known as the mucous membrane. This is kept moist, as we saw in studying the mouth cavity, by a slimy liquid known as mucus, secreted by the mucous cells. The mucous layer and the digestive juices that are poured into the alimentary canal provide a slippery surface over which the food can be readily moved. In the second place, outside this mucous membrane is a rich supply of thin-walled tubes, mainly blood vessels known as *capillaries* (from the Latin, meaning *hair*, since they are so tiny) which are well fitted to take up, or *absorb*, the liquefied food as soon as it is ready for diffusion through the tissues of the body. In the third place, layers of muscle constitute a considerable portion of the walls of the tube. By their contraction these muscles mix the food with the digestive juices and gradually force the food onward in its course.

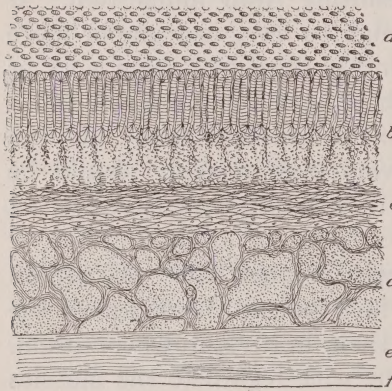


Fig. 103. — Section of the stomach wall

a, inner surface of the stomach, showing the openings of the gastric glands; *b*, base of the gastric glands; *c*, layer beneath the mucous membrane, containing many blood vessels; *d*, *e*, layers of muscle; *f*, outer coat of the stomach (peritoneum). This illustration represents a highly magnified section.

123. What digestive functions are carried on in the alimentary canal. Let us now get a general picture of the whole process of digestion and absorption. *In the mouth*

the food is cut up and ground by the teeth and at the same time thoroughly mixed with the saliva. Thorough chewing of food is most important since in this way the saliva is brought into intimate contact with the food particles. In this process the soluble food substances (sugars and some mineral matter) are dissolved, and the digestion of starch is begun.

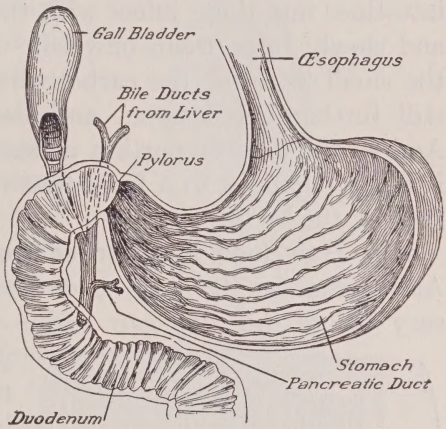


Fig. 104. — A section to show the interior of part of the alimentary canal

Duodenum is the name given to the beginning of the small intestine.

The pulpy food mass is forced by muscles down through the gullet *into the stomach* (Fig. 104) and may remain there for some time. In the stomach the saliva continues to digest starch for a varying length of time, and the *gastric juice*[1] is poured out from the gastric glands. By the contraction of the muscular walls of the stomach the gastric juice is distributed throughout the stomach's contents. The digestion of proteins is now begun and possibly that of other food substances. Meanwhile some of the more or less liquefied food is forced at intervals through the opening into the *small intestine*, and at the end of a number of hours the stomach has emptied itself in this way. The rennet ferment acts solely to change milk from a liquid to a soft solid. This is in preparation for its digestion by pepsin and hydrochloric acid.

[1] Gastric juice is composed of water, hydrochloric acid, and two ferments: *pepsen* and *rennet*. The acid digests some of the mineral matters.

While this action is going on in the stomach, the *bile* from the liver, the *pancreatic juice* from the pancreas, and the *intestinal juice* are oozing out upon the food in the small intestine. The contraction of the muscular walls of the intestines mix these juices with the partially digested foods and slowly force them onward. In their passage through the small intestine the carbohydrates and the proteins are still further acted upon, and the fats are also digested. And so the greater portion of each of the food substances is finally changed to a form that can be absorbed and utilized by the body.

124. How food is absorbed from the alimentary canal. All the changes that have been described thus far are necessary before the food can really enter the body; that is, pass through the various membranes into the capillaries that carry the blood. While it is possible that a certain amount of absorption may take place before the food reaches the intestine, this amount is probably small. In the intestine, however, all conditions are favorable for absorption: (1) the digestion of the available food materials has been largely completed; (2) the food lies for a considerable time in contact with a thin, moist membrane, beneath which are the thin-walled tubes (capillaries and lymph tubes) that are to absorb it; and (3) the small intestine of an adult is about twenty feet long, and its inner surface is still further considerably increased by a succession of circular ridges and depressions (Fig. 105) and by millions of microscopic projections known as *villi* (Fig. 106).

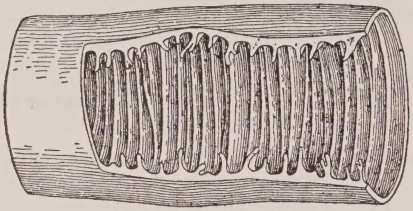


Fig. 105. — Portion of the small intestine
The wall has been cut away in order to show the ridges.

As the food proceeds through the small intestine, portions are absorbed when they are completely digested. Hence, the bulk of a given meal of food tends to become less and less, and by the time it enters the large intestine practically all of the available carbohydrates, proteins, and fats have been absorbed from the alimentary canal. The rather solid, indigestible substances that remain consist largely of the cell walls of plants, the tough fibrous parts of animal foods, and any undigested food substances. This residue should be regularly expelled from the body each day, for, if this waste material is allowed to accumulate, it decays, and, as a result of this decay, poisonous substances are almost sure to be formed and absorbed into the blood with serious results. The following are among the best ways of preventing this condition, which is known as *constipation:* (1) the drinking of large quantities of water (as much as half a dozen glasses each day), which tends to keep the intestinal contents from becoming too solid; (2) the eating of an abundance of vegetables, especially salads, fresh fruits, and breads made of whole wheat or Graham flour. These foods supply the bulk, or roughage, that is necessary to stimulate the muscles of the intestine to con-

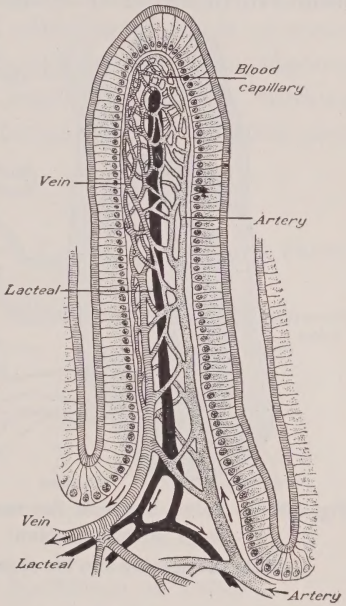


Fig. 106. — Section of a villus

Four million of these villi project from the inside wall of the small intestine. The thin-walled blood vessels and lacteals absorb the food.

tract and so force onward the waste substances rapidly enough to prevent decay.

125. What hygienic habits of eating are necessary. One should form the habit of eating slowly and of thoroughly masticating each mouthful of food, for in this way the food is thoroughly broken up and thus is prepared for rapid digestion not only in the stomach but in the intestines as well. The process of chewing likewise stimulates the flow of saliva. Saliva not only helps to digest food, but this juice also, when swallowed with the food, continues for a time the digestion of starch in the stomach and likewise stimulates to greater activity the glands in the walls of the stomach.

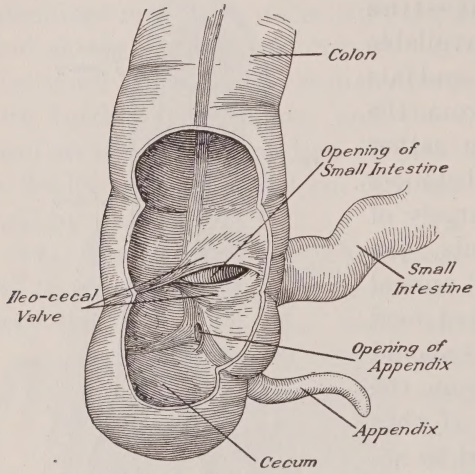


Fig. 107. — Valve between the small and the large intestine (colon)
Note the opening into the appendix.

The proper digestion of food depends in a large degree upon one's mental state. Experiments with animals and man have shown clearly that feelings of anger or worry stop the flow of digestive juices and the contraction of the muscular walls of the alimentary canal. Disagreeable topics should, therefore, be forgotten as far as possible while one is eating, and the mealtime should be made a season of enjoyment. "Laugh and grow fat" and "a merry heart doeth good like a medicine" are proverbs based upon sound principles of hygiene.

It has likewise been proved experimentally that digestive juices tend to be given off more freely at regular and stated intervals. Regular hours of eating, therefore, are of great importance, for nothing more commonly deranges the digestive system than the continual nibbling of foods or sweetmeats between meals. One should refrain from vigorous exercise or study for a time at least after eating; walking, on the other hand, and other forms of mild exercise seem to promote digestion.

NAMES, NUMBER, AND FUNCTIONS OF TEETH IN PREPARING FOODS FOR DIGESTION

NAME OF TEETH	NUMBER OF EACH KIND	USES OF TEETH
Incisors	8	Biting off food
Canines	4	Biting off food
Bicuspids	8	Grinding food
Molars	8 or 12	Grinding food

REGIONS, LOCATIONS, AND MATERIALS OF TEETH

REGIONS OF A TOOTH	WHERE SITUATED	MATERIALS IN EACH
Crown	Projects beyond the gum	Nerve pulp at center, covered by dentine; dentine covered by enamel
Neck	Covered by the gum	Nerve pulp at center, surrounded by dentine; dentine covered by enamel and cement
Root(s)	Embedded in a bony socket	Pulp at center, enveloped by dentine; dentine covered by bony cement

Digestive Glands

Name of Gland	Location of Gland	Name of Secretion and Where Poured Out	Action of Juices
Salivary	Walls of the mouth	Saliva; into mouth	Digests starch in the mouth and stomach
Gastric	Walls of the stomach	Gastric juice; into stomach	Partly digests proteins in the stomach
Pancreas	Between the stomach and small intestine	Pancreatic juice; into small intestine	Digests proteins, fats, starches in the small intestine
Liver	To the right of the stomach	Bile; into small intestine	Aids in digestion and absorption of fats in the small intestine
Intestinal	In walls of the small intestine	Intestinal juice; into small intestine	Digests sugar not ready for absorption and protein; also, probably both in mucous membrane

Summary

Digestive organs in man are: the alimentary canal and the *digestive glands*. The alimentary canal consists of the following parts: Mouth, throat, gullet, stomach, small intestine, and large intestine. In these organs the food is prepared for digestion, digested, and absorbed.

Digestive glands secrete juices which are conveyed to the cavities of the alimentary canal by *ducts*. Digestive juices except bile contain one or more enzymes.

Hygiene of digestion: Eat at regular times; chew food thoroughly; avoid unpleasant topics; eat slowly.

Care of teeth: Choose a diet based on the four rules sug-

gested in 59; eat some food that requires thorough chewing; avoid much candy and sweetmeats; clean the teeth thoroughly at least once a day; never bite substances that may break the enamel; visit the dentist twice a year.

Absorption of foods means the passage of digested foods from the alimentary canal through the mucous membrane and walls of capillaries or *lymph tubes* into the blood or *lymph*. Most of the absorption of food occurs in the small intestines, since the twenty feet of intestines with the circular ridges and depressions and the millions of villi afford a very extensive surface of mucous membrane for the process of absorption.

REVIEW QUESTIONS

1. What is meant by the alimentary canal, and what are its functions?
2. Name in order the parts of the alimentary canal, and give a brief description of the position and the relative size of each part.
3. What is meant by a digestive gland? Name and locate five kinds of digestive glands. State the digestive juice formed by each gland. Where does each juice enter the alimentary canal?
4. Describe the walls that enclose the mouth cavity. Give the characteristics of mucous membrane.
5. What are some of the functions of the tongue?
6. Name four kinds of teeth and give the use of each kind. Locate and give the number of each kind in a complete adult set, and show how each kind is adapted for its function.
7. What are the milk teeth and why should they be cared for?
8. Name and locate the three regions of a tooth. Name, locate, and give the use of each of five kinds of materials of which a tooth is composed.
9. Give as many reasons as you can for retaining and preserving the teeth.
10. Give specific directions for cleaning the teeth with reasons for each.
11. What precautions should be taken in using the teeth?
12. What advantages have natural teeth over false teeth?
13. Draw and describe the general structure of a cross section of the alimentary canal.

14. Name as many ways as you can in which the alimentary canal is specially fitted for its functions of digestion and absorption.

15. Describe in detail the changes that take place in food in the mouth cavity, the stomach, and the intestines.

16. What is meant by constipation? How may it usually be avoided?

CHAPTER XI

HOW CIRCULATION IS CARRIED ON IN THE HUMAN BODY

I. The Composition and Uses of Blood

126. How we know that food substances are circulated in the human body. We have traced the course taken by the various food substances from the time they enter the mouth until they have been digested and absorbed through the thin walls of the tiny capillary blood vessels in the walls of the intestines. Not only the lining of the alimentary canal has microscopic capillaries, but also practically every other part of the body has them. We know this to be true because even a slight cut or pin prick results in a flow of blood.

We can prove that food materials are distributed by this means, for if blood taken from any part of the body is tested for the different food substances, all classes of them are found to be present, though in slightly different proportions. In general we may say that the liquid portion of blood, known as *blood plasma*, contains the following:

Water	90+ per cent
Proteins	8+ per cent
Fats, sugars, and mineral matter	2− per cent

Thus we see that the food materials that were absorbed from the alimentary canal are available for use in every tissue of the body. It is evident, then, that there must be some means of transporting throughout the body the food substances that are absorbed from the alimentary canal. The system of organs that carries on this function of distribution is known as the *circulatory system.*

127. How oxygen is circulated in the human body. Not only must the cells of our bodies be supplied with food for growth and repair and for fuel, but also a supply of oxygen must be made available in each cell in order to release the needed energy. Now in what way is this oxygen carried? When we examine blood with the compound microscope, we find floating in the colorless plasma countless numbers of tiny bodies known as *red corpuscles* (Fig. 108). Each corpuscle is disk-shaped and hollowed out on both surfaces;[1] that is, it is *biconcave*. When they are spread out in a thin layer, each corpuscle has a faint yellow color. On a slide, however, these bodies have a way of arranging themselves like a pile of coins; and when the mass is sufficiently great, the red color becomes evident.

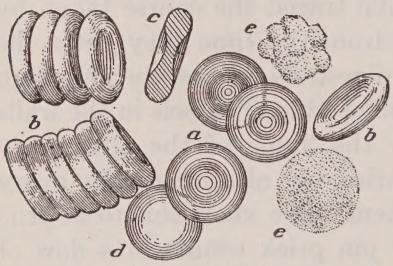


Fig. 108. — Blood corpuscles

a, red corpuscles seen from the side; *b*, red corpuscles, seen on edge, are run together in rows; *c*, section through middle of red corpuscle; *d*, red corpuscle swollen with water; *e*, white corpuscles.

Microscopic study fails to show the presence of a nucleus in any of these red corpuscles. Since, however, a nucleus was once present in each of them and has disappeared in an early stage, we may regard each corpuscle as a modified cell, especially adapted for distributing oxygen. They are able to do this because they contain a protein compound known as *hemoglobin*, in which iron is present. This compound has the remarkable power of chemically uniting with oxygen to form a bright-red compound known as *oxyhemoglobin*. When the red corpuscles pass through the working tissues that lack oxygen,

[1] A model of a red corpuscle easily can be made from a ball of putty, dough, or modeling clay by flattening it between two pieces of wood, and then pressing in the two surfaces between the thumb and finger. For description of white corpuscles, see pp. 205, 287, 289.

the oxygen is given up, the hemoglobin is thereby *reduced*, and the blood becomes deep-blue in color. When this reduced hemoglobin comes in contact with a new supply of oxygen in the lungs, it again becomes bright-red in color.

It is scarcely possible to picture to ourselves the enormous number of red corpuscles in human blood. It may help somewhat to state, as Dr. Stiles suggests, that about 5,000,000 corpuscles would fill a space the size of a coarse grain of granulated sugar; yet, if it were possible to represent the total surface of corpuscles in our own blood that is exposed to oxygen, it would perhaps equal the total area of four baseball diamonds. What a wonderful provision for absorbing and distributing oxygen!

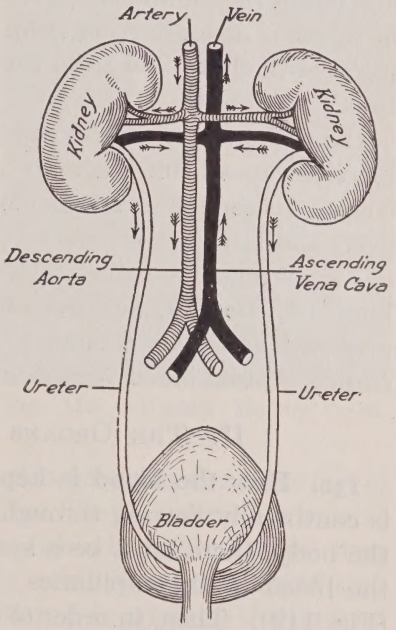


Fig. 109. — Kidneys
Note the blood supply to the kidneys and the tubes (ureters) from the kidneys.

128. How waste matters are carried by the blood. Whenever foods or tissues are burned, or oxidized, to release energy, carbon dioxid is formed. We have already shown that this compound is given off in considerable quantities from the lungs. Scientists have proved that this gas is carried from the working tissues to the lungs both by the plasma and also by the red corpuscles.

Other waste substances are formed in the body as a result of oxidation. Among these are water and *urea*, which contains the nitrogen waste formed by the breaking down of proteins. A large part of the water and urea is taken from the blood by the *kidneys*, two organs located in the abdominal cavity, on either side of the spinal column, and about the middle of the back (Fig. 109). A large amount of water is also given off from the lungs, as breathing on a mirror will show, and from the skin in the form of perspiration.

129. What is meant by the clotting of the blood. When blood escapes from the body, it is a liquid of a bright-red color. It soon changes in color to a dark-maroon, however, and later it thickens to the consistency of jelly. This dark-red mass is called a *blood clot*, and the process is known as *clotting*, or *coagulation*. Coagulation is of great practical importance, since it provides a natural means of closing injured blood vessels and of preventing loss of blood.

II. The Organs of Circulation

130. How the blood is kept in circulation. Since blood is continually flowing through the capillaries in all parts of the body, there must be a system of supply pipes bringing the blood to the capillaries. These are known as *arteries* (Fig. 119). Then, in order to carry away the blood from the capillaries of any part of the body, there must be another set of blood vessels. These are known as *veins*. Finally, in order to keep the blood in constant motion through the arteries, capillaries, and veins, considerable pressure is required. This pressure is exerted by a hollow muscular organ, the *heart*, which acts as a force pump.

While some of the facts relative to the movement of the blood in the body have been known for many centuries, it re-

mained for William Harvey, an English physician (Fig. 110) who lived about three hundred years ago, to demonstrate that there is a complete circulation of the blood. By this we mean that blood which is forced from the heart through the arteries, after passing through the capillaries, is brought back to the heart through the veins. Harvey's discovery has proved to be one of the most far-reaching discoveries that has ever been made in biology. We are now to study somewhat in detail the various organs of circulation.

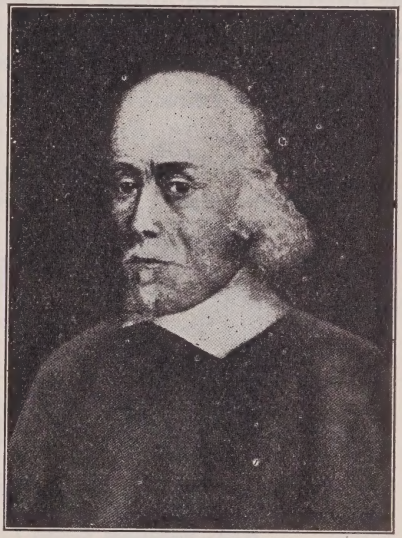


Fig. 110. — William Harvey (1578-1657)

131. What we know about the shape, size, and position of the heart. The heart is an organ about the size of one's fist and is shaped somewhat like an inverted cone with a blunt apex (Fig. 95). It lies behind the breastbone, near the middle of the chest cavity, with its more pointed end, or apex, extending toward the left side opposite the interval between the cartilages of the fifth and sixth ribs. Since the beat of the heart is felt most plainly near the apex, it is commonly but wrongly believed that the heart lies on the left side of the body. Let us imagine the front wall of the chest cavity to be removed; we would then see the soft pink lungs on either side and, between them, the heart (Fig. 95).

132. What we know of the structure and the action of the heart. If we should examine the upper part of the

heart, we would note on either side a rather thin-walled sac (Fig. 111). These two chambers of the heart are known as *auricles*. Now what is the use of the auricles, and why are there two of them? We have already learned that blood is returned to the heart from all parts of the body by means of veins. These veins empty into the auricles. To the left auricle is brought all the blood that comes from the lungs, while to the right auricle comes the blood from all other organs of the body.

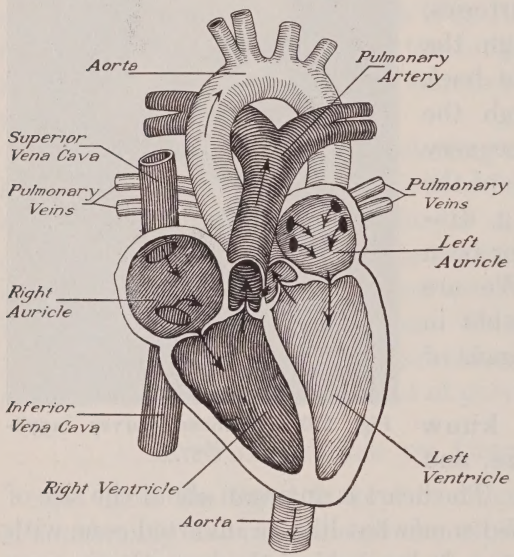


Fig. 111. — Structure of the heart

The arrows indicate the course of the blood to, through, and from the heart. Note the complete separation of the "right heart" from the "left heart."

If we should squeeze the lower part of the heart, we would find it to be firmer and much more muscular than the thin-walled auricles. A cross section of the heart about midway shows the presence of two chambers in this lower region, which are known respectively as the *right ventricle* and the *left ventricle*. Each ventricle lies immediately below and is connected with an auricle.

The blood from the veins, after entering the right or left auricle, passes downward through the opening into the corresponding ventricle, until the two ventricles are nearly

filled. Each auricle then contracts somewhat, thus distending the ventricles with the added blood. The walls of the more muscular ventricles now begin to close in upon the blood they have received, and we might naturally expect this blood to be forced back into the auricles. Such would be the case, were it not for the presence of flap-shaped valves that are forced out into a horizontal position, thus closing the opening into each auricle (Fig. 112).

Leading out from each ventricle is a large artery; the artery from the right ventricle carries blood to the lungs, and the artery from the left ventricle sends branches to all the other organs of the body. After the valves guarding the entrance from the auricles have been closed, the ventricles continue to contract and force out the blood which they contain into the arteries. When the ventricles are emptied and begin to relax, the blood that has been driven into the distended arteries would flow back into each ventricle, if it were not prevented from doing so by three pocket-shaped valves at the entrance of each artery, which fill out and thus block the openings from the ventricles.

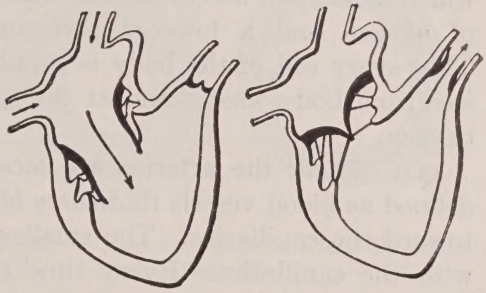


Fig. 112. — Action of the valves of the heart

At left, the position of the valves when the blood is flowing from auricle to ventricle; at right, the position of the valves when the blood is forced out from ventricle into large artery.

133. What the advantage is in having the heart divided into two distinct parts. The chambers of the right half of the heart have no direct connection with the chambers

of the left half; so we might well speak of a right heart as distinct from a left heart. The right heart receives from the tissues blood containing a high percentage of carbon dioxid and pumps this blood to the lungs. The left heart receives the blood from the lungs and pumps it to the tissues.

Since the blood, in passing through the capillaries of the lungs, gathers its supply of the necessary element oxygen and gives off the waste carbon dioxid, that part of the blood which enters and leaves the left heart has a high percentage of oxygen and a lowered percentage of carbon dioxid. Thus every cell of the body is supplied with blood largely free from body wastes and at the same time abounding in oxygen.

134. Where the arteries are located. Arteries may be defined as blood vessels that *carry blood away from the heart* toward the capillaries. The smallest arteries only connect with the capillaries. Every time the ventricles contract, the arteries leading from them are expanded, and this is true of every artery in the body. Most arteries lie beneath thick layers of muscle or beneath bones, which protect them from possible injury. In certain regions of the body, however, they lie close enough to the surface to be felt. Place the forefinger on the inner surface of the thumb side of your wrist. Do you feel a distinct throbbing called the *pulse?* This is caused by the enlargement of the artery at each heart beat, followed by a similar decrease in size. Consequently, when an artery is cut, the blood is forced out in spurts at each contraction of the ventricle.

135. What we know of the structure and the use of the arteries. When a piece of an artery of a higher animal or of man is examined, it is found that this blood vessel retains its tubular form, due to the presence of thick layers of

muscular and elastic tissue (Fig. 113). In the large arteries the walls are composed almost wholly of elastic tissue. When the blood is forced into them by the contraction of the ventricles, these arteries are expanded. The elastic walls then squeeze the blood forward toward the capillaries.

In the smaller arteries, in addition to the elastic tissue, the walls contain muscle tissue, which can relax or contract. This muscular tissue in the walls of these smaller arteries regulates the size of these blood vessels and so determines the relative amount of blood supplied to any particular organ. For example, when the face is flushed, the muscles in the tiny face arteries have relaxed more than is usual and so have permitted an additional amount of blood to enter the arteries in this region of the body. Pallor is caused by contraction of muscular walls in the small arteries of the skin. Under ordinary conditions the muscles in the walls of the arteries are neither contracted nor relaxed to their fullest extent. Rather their condition is midway between, and it is this condition that gives *tone* to muscle. The action of these arterial muscles is regulated by the *nervous system*, but it is in no direct way under the control of the will.

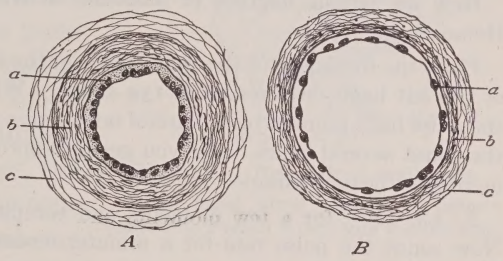


Fig. 113. — Cross section of an artery (*A*) and of a vein (*B*)

a, cells of the lining membrane; *b*, muscular and elastic tissue; *c*, outside connective tissue.

One of the mistakes in regard to the circulation made by those who studied it before Harvey's time is evident from

the name "artery." The earlier workers found these large blood vessels empty after death, and so they supposed these were air tubes; hence the name "artery" was given (from the Greek, meaning, *to hold air*). The arteries contract after the heart has stopped beating, and so the blood is forced out into capillaries and veins. This explains why arteries are found empty.

EXERCISE 43

How do various degrees of muscular activity affect the pulse rate? Home work.

Place the forefinger of the right hand on the inner surface of the wrist of the left hand, as directed in **134** above. While sitting quietly, count the pulse for a minute, being careful not to miss any of the beats. Repeat the count several times, until you get an approximate agreement in the number of beats a minute.

1. Lie down for a few moments and completely relax your muscles. Now count the pulse rate for a minute, repeating the count as before. Record your result.

2. In a similar way make a record of your pulse while you are sitting still.

3. Determine likewise the pulse rate when you are standing.

4. Take some vigorous exercise for several minutes (*e.g.* setting-up exercises, running up stairs, or riding a bicycle). Now determine and record your pulse rate.

5. (Class exercise.) In a table like the following record the number of pupils in your class with pulse rates corresponding to the headings of the various columns named below.

	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110–119	120+
Lying down .									
Sitting . . .									
Standing . .									
After vigorous exercise . .									

6. What do you conclude, therefore, as to the effect on the pulse rate of varying degrees of muscular activity?

136. What we know of the position, number, and structure of the capillaries. As we trace the arteries farther and farther from the heart, we see that they divide and subdivide until very small branches are formed. That these fine branches are still arteries is proved by the fact that muscular and elastic tissue are present in their walls. Finally, however, these tiny blood vessels become continuous with still smaller tubes, the capillaries. So numerous are the capillaries that one can not push the point of a needle for any considerable distance into any organ of the body without piercing a number of them. These smallest of blood vessels communicate freely with one another and form a complicated network of tubes that bring blood to all the cells of the body.

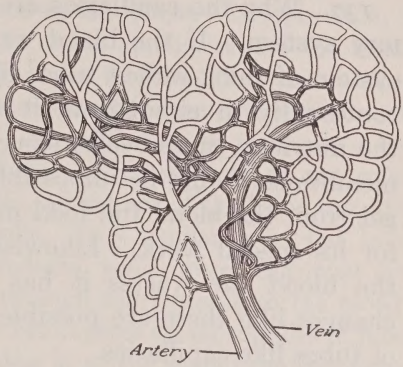


Fig. 114. — Network of capillaries

These small blood vessels are shown connecting a small artery with a small vein.

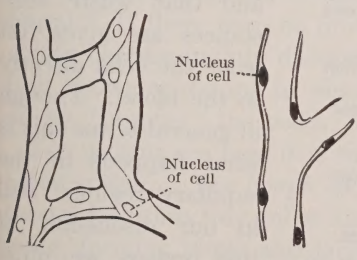


Fig. 115. — Structure of capillaries

At left, surface view; at right, lengthwise section. Note that the wall has only the thickness of one cell.

In structure the capillaries are extremely simple. At the points in the blood system where arteries end and capillaries begin, muscular and elastic tissues disappear. Indeed the walls of capillaries are formed only of a single layer of very thin-walled cells (Fig. 115). We have in this arrangement one of the best pos-

sible conditions for the process of osmosis, as we shall now see.

137. Why the capillaries are so important in the circulatory system. If the blood were kept constantly within a system of thick-walled tubes like the arteries, even though continually in circulation, it would be unable to help in the nutrition of the cells, since osmosis through such thick membranes would be impossible. Each cell must somehow get from the blood the food materials and oxygen it needs for its special work. Likewise each cell must give off to the blood the wastes it has formed by oxidation. Exchanges like these are possible only through the thin walls of tubes like capillaries.

138. What lymph is. From our discussion of the structure and use of the capillaries, one might infer that the liquid food substances of the blood pass directly from the thin-walled capillaries into the tissue cells and that waste substances are given off from the cells directly to the blood. Though in general terms this is what happens in the capillary regions, still in our discussion of this process we must take into account the presence of a watery, colorless liquid known as *lymph*, which surrounds practically every cell of the body (Fig. 116). As the blood passes through the capillaries, part of the plasma diffuses out and thus forms the liquid to which we have just referred. One may say, therefore,

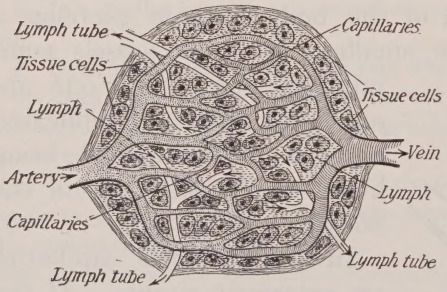


Fig. 116. — Lymph spaces and tubes
Note the intimate relation of the lymph to the cells and to the capillaries and lymph tubes.

that *lymph is blood minus the red corpuscles.* The "water" that is squeezed out of a blister is practically like lymph in its composition.

139. What changes take place in the lymph. Lymph, then, is found always between the walls of the capillaries and the tissue cells. In other words, the cells of the muscles, glands, and other organs live in lymph. It is obvious, therefore, that lymph can act as a medium of exchange — a middleman, so to speak — between the blood in the capillaries and the liquid in the cells. The food and oxygen by osmosis can get out of the blood into the lymph and thence into the cells. In a similar way, but in a reverse direction, the waste products, which every cell must get rid of, can pass from the cell through the lymph into the blood. Hence, while it is true that the blood gives up its supplies of food and oxygen to the cells and takes in at the same time the waste materials, all these changes take place through the lymph, which, on one side, is in direct contact with the capillary walls and, on the other, bathes the cells in its fluids.

140. How a surplus of lymph is returned to the blood circulation. Lymph is derived both from the blood and from the cells. Hence there is a constant tendency for it to increase in quantity. The question may now be asked, What becomes of this excess of lymph? If there were no provision for draining it off, the tissues would become unduly distended. Such is the case in the condition known as *dropsy*, in which the excess liquid has to be drawn off by "tapping" the body.

Let us now see how it is that this valuable liquid reënters the blood stream. The *lymph spaces* between the cells in the various tissues lead into tiny tubes known as *lymphatics*, which gradually unite, forming larger and larger tubes. These finally collect the lymph into two tubes which empty into veins in the neck region (Fig. 117). There are small valves along the course of the lymphatics that prevent the lymph from taking a backward course.

141. What we know of the position and structure of the veins. The blood that comes from the capillaries returns to the heart through the veins. Veins may be seen on the

back of the hand as a branching system of blood vessels. Many veins, like those on the hand, lie near the surface

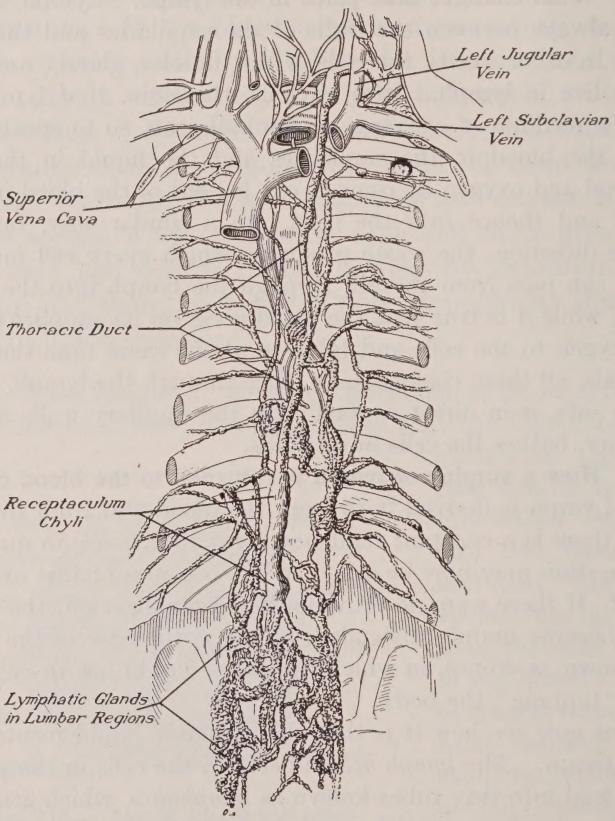


Fig. 117. — Lymph tubes

These return the lymph to veins in the neck.

while most of the arteries are deeply buried among the other tissues. Unlike the arteries, veins have no pulse.

When the veins are emptied of blood, they immediately collapse. This is due to the fact that their walls have far less muscular and elastic tissue than have the walls of the

arteries (Fig. 113). Veins are provided with valves shaped much like the valves at the mouth of the large arteries leading from the heart, consequently the blood can flow only toward the heart, for as soon as it begins to flow in the opposite direction, these valves are immediately filled, and the passage is obstructed (Fig. 118).

142. What course the blood takes through the body. Having now completed our survey of the structure and action of the heart and of the blood vessels, we are ready to study the blood system as a whole and to learn how the blood goes to, through, and from the various organs of the body. Let us now follow the course of a drop of blood from the time it leaves the left ventricle until it again returns to this chamber of the heart.

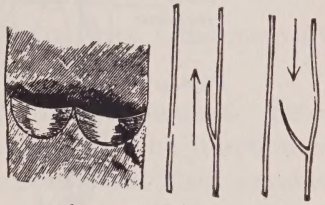


Fig. 118. — Structure of a vein

A, vein laid open to show the shape of the valves; *B*, section of vein showing the valve open; *C*, section of vein showing valve closing to prevent the flow of blood backward.

When the left ventricle contracts, the blood is forced out into the largest artery of the body, which is known as the *aorta*. This blood vessel forms an arch (Fig. 119), from the upper portion of which branches extend to the head and the arms. The aorta then continues downward through the chest and abdominal cavities, supplying on its way the various organs of these regions (Fig. 119). It then divides into two arteries that continue down the legs. Each of these larger arteries that we have mentioned divides again and again, until finally the blood is forced through a network of very fine capillaries in the various organs to which the capillaries extend.

From these capillaries blood passes into tiny veins, which carry all the blood into larger veins and finally empty it into two large veins, one from the upper part of the body, the other from the lower part of the body. These two veins empty into the right

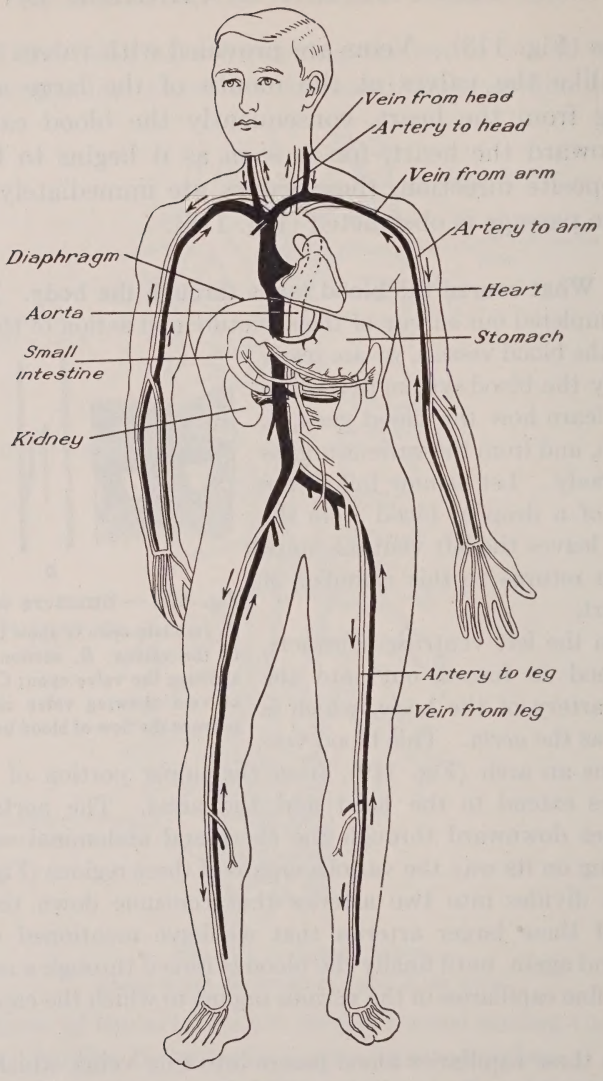


Fig. 119. — Course of the blood through the body

Arteries are shown in white; veins in black.

auricle of the heart. Thence the blood passes into the right ventricle.

The right ventricle by its contraction drives the blood through an *artery* to each of the lungs, where its many branches finally reach the countless capillaries in the interior of these organs. *Veins* now receive the blood and convey it to the left auricle, whence it flows downward into the left ventricle. About one minute is usually required for a quantity of blood equal to the entire blood of the body to complete this circuit from the left ventricle back to this chamber of the heart.

III. Hygiene of the Blood and of the Circulatory Organs

143. What conditions affect the red corpuscles. Since supplying oxygen to the various tissues is the function of the red corpuscles, it is very important that their number be sufficient and that they be kept in a healthy condition. To this end *an abundance of sleep, fresh air, exercise, and nutritious foods are the essential conditions.* Everyone knows that the face looks pale after loss of sleep or when food or fresh air is insufficient or during periods of physical inactivity, and this appearance indicates a lack of red corpuscles. Habitual paleness, or *anemia,* is a disease requiring medical treatment. A good complexion, therefore, is very largely dependent on good health. Paint, powder, and other cosmetics will not give such a complexion. When used habitually and to excess, they are often a source of permanent injury to the skin.

144. What conditions affect the blood plasma. All the nutrition of the tissues is finally derived from the blood, and all the food substances of the blood come from the foods that we eat. If these foods are insufficient or of an improper kind, the plasma will of course be deprived of necessary ingredients, and the organs must inevitably suffer in con-

sequence. In supplying material for the blood, one must not follow entirely the dictates of the taste. For instance, if we are very thirsty, we are tempted to drink rapidly a great quantity of ice-cold liquid, although a smaller quantity of water, passing slowly through the mouth, will alleviate thirst much more quickly and completely. Sugars are often eaten in too large a quantity instead of the more important protective foods.

145. What the effect of exercise is on the heart. The pulse rate is slowest when we are asleep. As the activities of the day begin, the heart beat is quickened, and after violent exercise this organ may beat as rapidly as twice a second. Exercise, when properly regulated, is undoubtedly beneficial to every organ of the body. Hence the heart should be kept in such a vigorous condition that it is ready to meet the ordinary requirements of everyday life as well as the strain that may come in such emergencies as escape from threatening danger or recovery from disease.

It is possible, however, to overstrain the heart muscle by exacting from this organ too violent or too prolonged activity. Such may be the case in sprinting or in long distance runs or in bicycle riding. These sometimes result in permanent harm to the walls or the valves of the heart. Before a youth takes part in violent athletic contests, he should be examined by a competent physician.

146. What the effect of exercise is on the blood vessels. When one is using the muscles actively, greater oxidation of the tissues goes on, and a larger amount of blood is needed to supply the oxygen and to remove the wastes formed by this increased oxidation. The muscular walls of the small arteries relax in the organs that are especially active, thus supplying these organs with more blood. Since altogether there is only about 3½ to 4½ quarts of blood in

the whole body of the average adult weighing 150 pounds, it is manifestly impossible to have an increased supply of blood in the organs of digestion, in the muscles, and in the brain at the same time. This is the reason why it is unhygienic to exercise violently or to carry on any considerable degree of mental activity immediately after a hearty meal. Mild exercise, however, is said to be distinctly beneficial.

147. How blood flow in wounds may be stopped. One can tell when an artery has been cut, for then the blood comes out in spurts. Since the blood is on its way from the heart, the flow can be stopped or lessened in this kind of accident by applying pressure on the side of the wound nearest to the heart.[1] Thus, if the finger is cut deeply and the blood jets forth, a strong cord or a rolled handkerchief should be tied loosely about the wrist, a wad of paper or a pebble should be placed directly beneath the knot and upon the artery, a pencil or a piece of wood should then be run through the loop, and the cord or handkerchief should be twisted until the blood flow is stopped by the pressure. This application is known as a *tourniquet*.

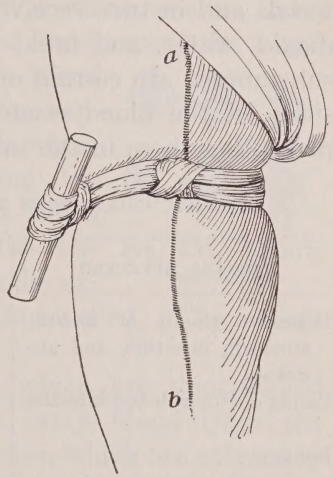


Fig. 120. — Tourniquet, applied below the knee
a, *b*, course of the artery.

When the blood flows evenly from a wound, it is an indication that a vein has been cut. The tourniquet (Fig. 120)

[1] Every pupil should practice the method of applying a bandage in accordance with the directions given in this section. For further treatment of cuts and bruises see 202.

should then be applied on the side of the cut farthest from the heart. Bleeding from the nose can usually be stopped by holding the head erect and applying ice or cold water to the bridge of the nose or to the back of the neck.

148. Changes in the composition of the blood. The composition of the blood is continually changing while it is passing through the capillaries of the various tissues and organs. In every tissue of every organ the blood in the capillaries gives up to the lymph oxygen and food materials and in turn receives from the lymph wastes (carbon dioxid, water, and urea) formed by the oxidation of food substances. In certain organs other changes in the composition of the blood occur which may be made clearer by presenting them in the tabular form which follows:

SPECIFIC CHANGES IN THE COMPOSITION OF THE BLOOD

ORGANS AFFECTED	BLOOD LOSES	BLOOD GAINS
Digestive glands of mouth, stomach, intestine, and abdomen	Materials needed for the manufacture of digestive juices	
Lining of stomach and intestine		Water and digested food substances
Lungs	Carbon dioxid and water	Oxygen
Kidneys and skin	Water and urea	

SUMMARY

The *blood* is composed of semisolid constituents, the *corpuscles;* liquid constituents, *water* and *digested foods;* gaseous constituents, *oxygen* and *carbon dioxid.*

The *corpuscles* are of two kinds, the red and the white. The *red corpuscles* contain *hemoglobin* which absorbs and carries oxygen from the lungs to the working cells. The

white corpuscles (Fig. 121) are important aids in protecting the body from disease.

The *liquid part of the blood* called *plasma* consists of *water* and *digested food* substances needed by the cells and *wastes* that have been removed from the cells.

The *gaseous constituents* are *oxygen* absorbed in the lungs by the hemoglobin in the red corpuscles and *carbon dioxid* absorbed from the cells of the body and carried by the plasma and red corpuscles.

The *heart* consists of a *right auricle* which receives blood through veins from all parts of the body except the lungs; a *right ventricle* which pumps the blood received from the right auricle to the capillaries of the lungs; a *left auricle* which receives blood through veins from the lungs; a *left ventricle* which pumps blood received from the left auricle to the capillaries of all the organs of the body except the lungs. The auricles are thin-walled. The ventricles are thick-walled.

Fig. 121. — White corpuscles

The *blood vessels* are: *arteries*, which are thick-walled muscular and elastic tubes that carry blood from the ventricles to the capillaries; *capillaries*, which are extremely thin-walled tubes that convey the blood from the arteries to the veins; *veins*, which carry blood from the capillaries to the heart. Veins have valves that prevent the backward flow of blood. All changes in composition of the blood occur in the capillaries.

The *lymph vessels* (lymphatics) are tubes that carry a fluid known as lymph from the tissues to veins in the neck. *Lymph* is a liquid found between the capillaries and the cells and also in the *lymph tubes*. *Lymph* consists of water and other *food* substances received from the blood and from

the villi of the small intestine and *wastes* received from the tissues.

REVIEW QUESTIONS

1. Where are capillaries found in the body? How may this be proved?
2. What in general is the composition of the blood plasma?
3. What is meant by the circulatory system?
4. Describe the shape and size of the red corpuscles. Give some idea of the extent of their combined surfaces. What is their function?
5. Define hemoglobin.
6. Name three wastes of the body. State how each is carried in the blood and by what organ or organs each is excreted from the body.
7. Describe clotting, or coagulation, of the blood. State why this process is useful to the body.
8. Name four kinds of organs that make up the circulatory system of man, giving the use of each.
9. Give an account of the work of William Harvey.
10. Describe the shape and state the size and position of the human heart.
11. Name the four chambers of the heart and state the function and action of each.
12. Locate and describe the work of each of four sets of valves concerned in the action of the heart.
13. What is the principal difference in the composition of blood in the right and left heart? What is the advantage of the two distinct parts to the circulation?
14. Describe the position, structure, and action of the large arteries. How is the pulse accounted for? How is the amount of blood supplied to the different organs regulated? What is the meaning of the word "artery"? Describe the structure and action of small arteries.
15. Where are capillaries found with reference to arteries? What is their structure? What is the function of capillaries, and how are they adapted for this function?
16. Describe the composition and use of lymph. What changes take place in lymph? How is lymph returned to the circulation?
17. Give an account of what blood gains and what it loses in the capillaries in all tissues of the body; in digestive glands; in the lining of the alimentary canal; in the lungs, the skin, and the kidneys.

18. Describe the position, structure, and size of the veins. How do veins differ in structure from arteries? From capillaries?

19. Why is it important to keep the red corpuscles in good condition? The blood plasma? Give directions that should be followed to accomplish these ends.

20. Give an account of the effect of exercise on the heart and on the other blood vessels. What precautions should be taken in the matter of violent exercise?

21. How should blood flow from an injured artery be stopped? From an injured vein? Describe a treatment for nosebleed.

CHAPTER XII

HOW LIVING ORGANISMS BREATHE

149. Why breathing is necessary in living things. For the release of energy all living things require a constant supply of oxygen[1] and all living things are constantly producing carbon dioxid. Therefore, some means must be provided whereby every living thing may secure its oxygen supply and eliminate the waste carbon dioxid from the body. This part of the process of respiration is commonly known as *breathing*.

I. Structure and Functions of the Breathing Organs of Man

150. What course air takes in order to reach the lungs. The most important organs that have to do with our breathing are the lungs. They are located within the chest cavity and have no immediate contact with the outside air; hence there must be air passages leading to the lungs.

In ordinary breathing air enters the body through the *two nostrils* (the left one is shown in Fig. 122). It then passes through the two *nasal passages* into the throat cavity. In the lower region of the throat is the slitlike *glottis opening*, through which the air enters the *larynx*, or voice box. This organ, commonly known as "Adam's apple," projects somewhat on the front of the neck.

Below the larynx is the continuation of the *windpipe*,

[1] Dr. E. C. Schneider of Wesleyan University and of the Mitchell Aviation Field, who has carried on important experiments with reference to the respiration of aviators and mountain climbers, is authority for the statement that each one of us has a total supply of oxygen in the body sufficient to last *only four minutes*.

which, just above the level of the heart, divides into two main branches (Fig. 123). One of these branches supplies air to the right lung; the other to the left lung. Within the lungs these tubes branch off into a vast number of very small pipes called the *bronchial tubes*. The tiniest divisions of these tubes open into extremely thin *air sacs*. Let us

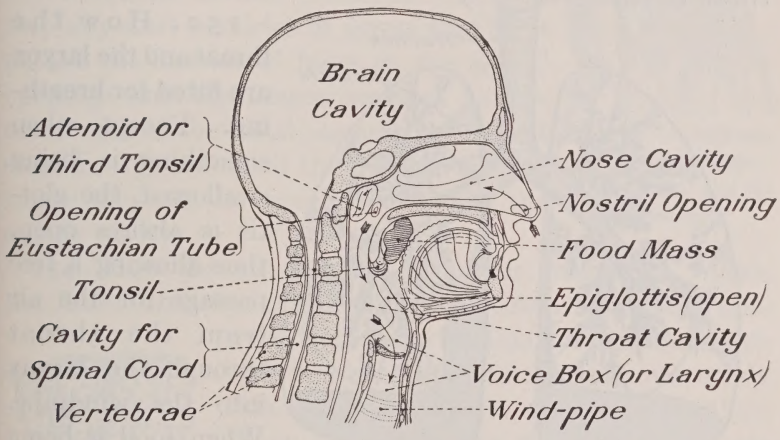


Fig. 122. — Section of the head

Follow the course of the air from the nose to the windpipe. Note the position of the epiglottis.

now consider somewhat in detail each of these various air passages.

151. How the nasal passages are fitted for breathing. The openings into the nasal passages are guarded by numerous projecting hairs, by means of which a considerable amount of dust is kept from entering the body. The nose itself is lined with mucous membrane which covers the whole interior of the nasal chambers and collects most of the dirt and germs that have passed the hairs in the nostrils, unless the amount of these foreign substances is excessive.

The incoming air absorbs a considerable quantity of water from the mucous secretion in the nose, and in cold weather the air is warmed by the blood in the capillaries that run beneath the mucous membrane. The air, thus cleaned and warmed and moistened, enters the throat cavity.

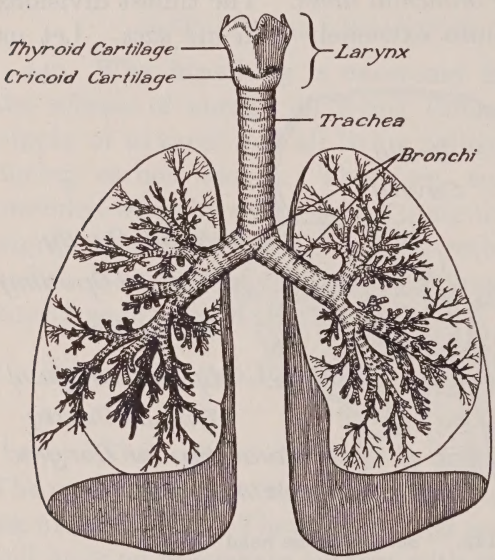


Fig. 123. — Air passages and lungs
Note how the tubes branch out in the lungs.

152. How the throat and the larynx are fitted for breathing. Except when something is being swallowed, the glottis is always open, thus allowing a free passage for the air from the throat through the larynx into the windpipe. When food is being swallowed (Fig. 99), it is, of course, important that the windpipe be closed. This is accomplished by a little trapdoor called the *epiglottis* (Fig. 122). If one puts the finger on the larynx region of the neck and then swallows, one can feel this organ rising to meet the epiglottis. Within the voice box are two thin membranes called *vocal cords* that may be set in vibration by the inspired or expired air. These vocal cords help to produce the various tones of the voice.

153. How the lining of the air passages is adapted for filtering the air. The mucous lining of the nasal cavities and

of the windpipe and its branches is especially interesting. The cells that cover these passageways have on their exposed surfaces minute projections of protoplasm, called *cilia* (Fig. 124). These wave upward toward the throat with a quick movement and then more slowly recover their former positions. In this way any dust particles or germs that have passed the barrier of hairs at the nostril openings and the mucus secreted by the membrane of the nasal passages are moved steadily upward until they reach a point where they can be coughed out into the mouth cavity.

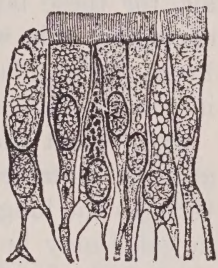


Fig. 124. — Cells lining the windpipe
Note the cilia and the mucous cells.

154. How the air sacs are fitted for breathing. When the finest branches of the bronchial tubes are traced outward from the windpipe, we find that each ends in a branching *air sac* with extremely thin walls of elastic tissue (Fig. 125). When air comes into these sacs, they are expanded; but as expiration begins, their elastic walls help to force outward through the branches of the windpipe the air that has been taken into the lungs.

Fig. 125. — Two air sacs
Note the air tube (*a*) and the branches of the air sac (*b*) that provide surface for the interchange of gases.

155. How the lungs are supplied with blood. The *artery* supplying the lungs, as we learned in **132**, arises from the right ventricle and soon divides into two branches, one for the right lung and one for the left lung. Within the lung tissue each artery divides into small branches that follow the course of the bronchial tubes to the air sacs. Here the arteries communicate with a maze of capillaries, which run within the

thin lining of the air sacs. It is here that the exchanges take place between the blood, the lymph, and the inhaled air, for these liquids and gases are separated only by the extremely thin walls of the air sacs and of the capillaries. From the capillaries of the lungs the blood finally collects into *veins* that convey the blood to the left auricle.

156. What changes take place in the color of the blood after it is mixed with oxygen. When the blood passes through the lungs, it absorbs oxygen. The resulting change in color may be seen by the following experiment. Pour into a glass bottle a few spoonfuls of blood of beef that has been prevented from clotting by being stirred vigorously with a bunch of twigs, and stopper tightly. When the bottle is shaken violently, the blood is mixed with the oxygen in the bottle, and the dark-maroon color changes almost instantly to a bright-scarlet. The pupil doubtless will have observed that the blood in the veins on the back of the hand is blue. But whenever blood flows from any of the veins in the case of a cut, the color is always bright-red, after the blood comes in contact with the oxygen of the air.

EXERCISE 44

To determine the amount of enlargement of the chest cavity during inspiration. Home work.

Force the air out of the lungs as completely as possible. Draw a tape or cord around the chest under the armpits, keeping it reasonably tight, and measure the girth of the chest.

1. State what you have done and record in inches the measurement thus determined.
2. Inhale as much air as possible and again record the chest measurement as directed above.
3. State the difference in the measurements thus obtained.
4. What is your conclusion, therefore, as to the amount of the enlargement of the chest cavity during inspiration?

157. How air is taken into and given off from the lungs. The chest cavity is so constructed that its capacity can be considerably increased and then decreased. When we make the cavity smaller by forcing in the ribs and raising the

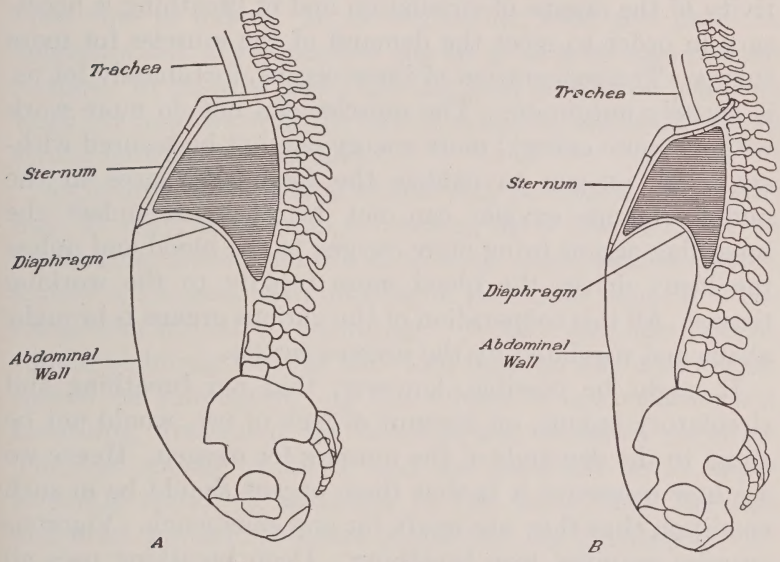


Fig. 126. — Breathing movements

Note the difference in the position of the breast bone (sternum) and diaphragm during inspiration (*A*) and expiration (*B*). The white space in the chest in *A* indicates the increase in the size of the chest cavity after expansion.

diaphragm (Fig. 126, *B*), air is driven out through the air passages; in other words, we *exhale*. *Inhaling*, or taking in air, on the other hand, is accomplished by increasing the size of the chest cavity. This cavity is made larger by moving the ribs outward and upward and by flattening and so lowering the diaphragm (Fig. 126, *A*). The air in the cavity expands to fill the larger space and so becomes rarefied and the outside air is forced in to fill the partial vacuum.

II. Hygiene of the Breathing Organs

158. What effect exercise has on breathing. Not only does the heart beat more rapidly during exercise, but the rate of breathing also increases. This increase in the activity of the organs of circulation and of breathing is necessary in order to meet the demand of the muscles for more energy. The coöperation of these organs, fortunately for us, is entirely automatic. The muscles can not do more work without more energy; more energy can not be secured without more oxygen to oxidize the food substances in the muscles; more oxygen can not be obtained unless the breathing organs bring more oxygen to the blood and unless the heart drives the blood more rapidly to the working tissues. All this coöperation of the various organs is brought about and regulated by the *nervous system.*

It might be possible, however, that our breathing and circulatory organs, on account of lack of use, would not be equal to the demands of the muscles for oxygen. Hence we see how necessary it is that these organs should be in such condition that they are ready for any emergency. Vigorous exercise requires deep breathing. Deep breathing uses all parts of the lungs and tends to keep them not only in a condition such that they may be able to take in more air when needed, but also to resist disease more successfully.

Since the effects of deep breathing made necessary by vigorous work or play are so beneficial, it has been thought by many people that deep breathing exercises alone would be desirable. Such exercises, however, are not advisable. Since forced breathing when very long continued has been found to be actually harmful, such exercises should be carried on either with great moderation or not at all.[1]

[1] See Stiles' *Human Physiology*, p. 301.

159. What the causes and treatment of suffocation are. We have emphasized the fact that the body must be continually supplied with oxygen and that the wastes produced by oxidation must be constantly removed. If this process is interrupted, even for five minutes, fatal results are almost sure to follow. If, in swallowing, food gets past the epiglottis into the windpipe, the air is shut off and *choking* results. In cases of this kind the head should be held forward (or downward in the case of a child), and sharp blows struck between the shoulders.

Suffocation is some interference with the process of breathing. It may result from a blocking up of the windpipe as in choking, from inclosure in a small space with a limited supply of oxygen, from inhaling of poisonous gases, or from immersion in water (drowning). In any case the patient should be brought out at once into fresh air and a physician should be summoned. If the subject is unconscious but breathing, treatment for fainting and shock is required. The feet should be raised and the head left low. Apply aromatic spirits of ammonia to the nose. Rub the legs and arms toward the heart to quicken the circulation. If, however, breathing has ceased, *artificial respiration* should be attempted at once.

Do not waste time trying to get the harmless water out of the stomach. Lay the subject face downward on a flat surface or with the head slightly down hill. Turn the head to one side, extend the arms above the head and place one hand under the face with the finger tips under the mouth to protect both the mouth and nose from dirt. Kneel astride the subject's knee on the side toward which the face is turned. Apply pressure immediately over the lower ribs. Move the weight of the body slowly downward and forward for about three seconds (Fig. 127). This movement should

force some of the vitiated air from the lungs. Do not slide or bend the arms. The shoulders should be behind the hands so that the pressure is thereby exerted forward. Now snap the hands off, thus allowing the lungs to fill with fresh air (Fig. 128). The operator should then slowly and

Courtesy American Red Cross

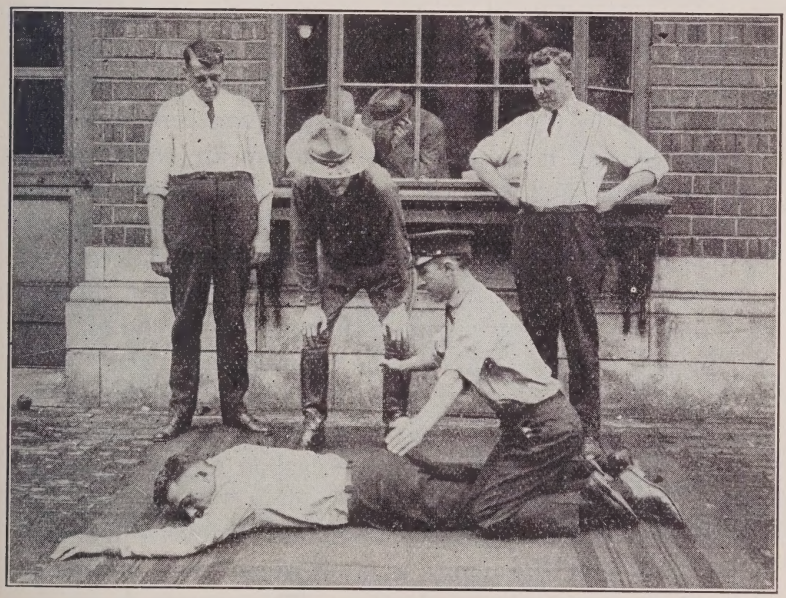
Fig. 127. — Artificial respiration (Schaefer method)
Forcing air from the lungs. Members of the life-saving squad of the Akron Fire Department.

deliberately swing his body backward to an upright position.

At the end of two seconds again place the hands in position and apply pressure as before. Thus five seconds are allowed for a complete respiration, or twelve respirations per minute. This is fast enough and will allow one to continue for some time without exhaustion. If, however, it

becomes necessary to have some one relieve you, be sure that it is done without a break, and see that your successor uses the same timing that you have without losing the rhythm.

To assist in properly timing these movements, repeat



Courtesy American Red Cross

Fig. 128. — Artificial respiration

Snapping off the hands to allow the lungs to fill with air.

either silently or aloud during the period of pressure "out goes the bad air" and during the period of release "in comes the good," or count slowly, "one, two, three" for pressure and "four, five" for release, one count for each second.

Cases have been reported of persons who have been under water as long as thirty minutes and yet have been resuscitated after five and one-half hours of continuous work.

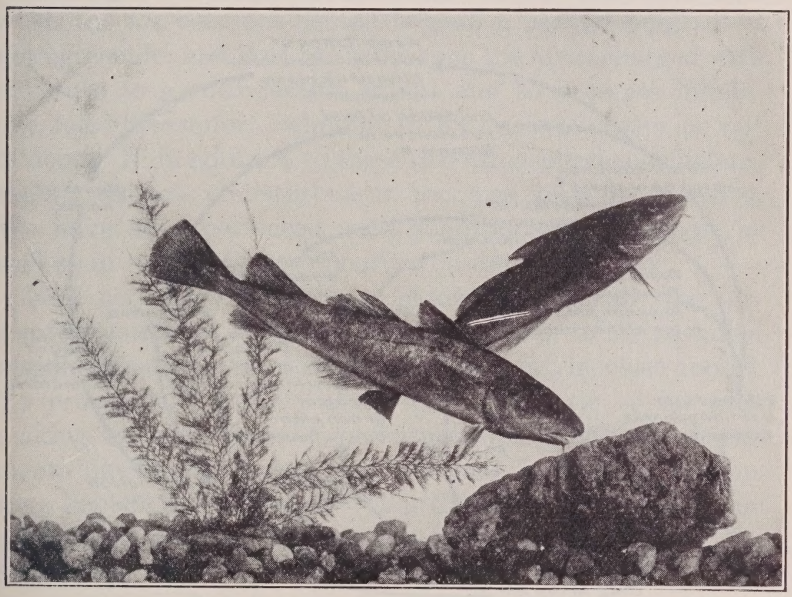
There is no certain sign by which the layman can determine that it is too late for artificial respiration. Efforts should not be abandoned for at least two hours.

160. How the composition of the air is kept nearly the same from year to year. All living things are using up the oxygen of the air in order to release the energy of the food stored in the cells and are giving off carbon dioxid to the air. The burning of wood, coal, gas, and other fuels all over the world likewise results in depleting the oxygen of the air and in the addition of large quantities of carbon dioxid. Hence it would seem that the air would finally become so charged with carbon dioxid and become so lacking in oxygen that life on the earth would finally cease to be possible. Analyses of outdoor air of city and country, however, in various parts of the world show that the relative amounts of oxygen and carbon dioxid in the air vary but little. Now how can this be explained?

Green plants, when exposed to light, take the carbon dioxid from the air in the process of sugar manufacture; but since only the carbon of the carbon dioxid is needed, the excess oxygen is returned to the air. The plant of course all the time needs oxygen to bring about the release of energy; but in the light the plants give off much more of this gas than they can use in respiration. This oxygen is set free in the atmosphere in land plants and in the water in plants living under water. Hence we see why it is possible to keep an aquarium running for a long time without changing the water if the animals and plants in the water are properly balanced (Fig. 129).

The beneficent activities of green plants all over the globe, together with the constant mixing of the atmosphere due to the world-wide action of winds, will help us to understand how the air is kept so nearly in a constant condition

as regards the relative amounts of oxygen and carbon dioxid. The processes by which the carbon of the carbon dioxid is made a part of foods and fuels by plants and then in turn is given back to the atmosphere as carbon dioxid



Courtesy N. Y. Zoological Society

Fig. 129. — Balanced aquarium

What do the fish supply to the green plants? What do the plants supply to the fish?

by the respiration of both plants and animals comprise what is known as the *carbon cycle* (Fig. 130).

161. How the composition of the air is kept suitable for breathing. In enclosed spaces, such as living rooms or the rooms where people congregate — halls, churches, theaters, and schools — where the air is prevented from free movement and from mixing with the outer atmosphere, the air soon becomes stuffy, and the occupants suffer discomfort

which increases with the number of people. This, if carried to an extreme, would result in the death of the occupants of such a room. Since no living thing can exist in an atmosphere consisting to any considerable extent of carbon dioxid, it has been thought that carbon dioxid given off

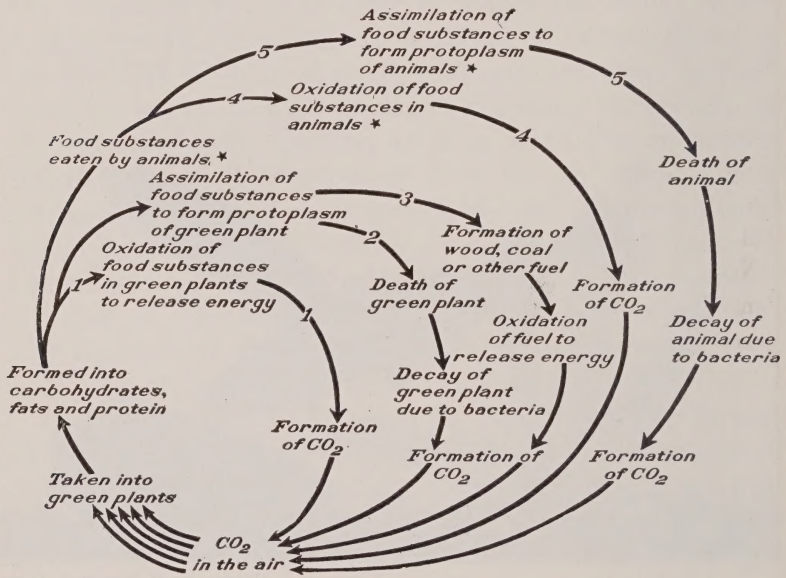

Assimilation of food substances to form protoplasm of animals *
Oxidation of food substances in animals *
Food substances eaten by animals *
Death of animal
Assimilation of food substances to form protoplasm of green plant
Formation of wood, coal or other fuel
Oxidation of food substances in green plants to release energy
Death of green plant
Formation of CO_2
Oxidation of fuel to release energy
Decay of animal due to bacteria
Formed into carbohydrates, fats and protein
Decay of green plant due to bacteria
Formation of CO_2
Formation of CO_2
Formation of CO_2
Taken into green plants
CO_2 in the air
1
2
3
4
5

Fig. 130. — The carbon cycle

Trace the carbon and oxygen in the successive cycles (*1*, *2*, *3*, *4*, and *5*).

from living things is the principal cause of the discomfort arising from stale air and, in extreme cases, of the death of the people or of the animals subjected to such air.

It is of course true that no animal or plant can live in pure carbon dioxid, since carbon dioxid does not support oxidation. But neither does nitrogen support burning, and death will result likewise in an atmosphere of nitrogen alone.

★ This is equally true of plants without chlorophyll.

It likewise has been thought that there are unknown poisonous substances exhaled by the body that render the air harmful. But of these there has yet been no proof.

Why, then, does air become unsuitable for breathing in rooms where people congregate? Everyone knows that, when the air becomes heated beyond a certain point, it is not agreeable; and if at the same time the air is charged with moisture to a considerable extent and so becomes humid, one feels discomfort, whether in an enclosed room or out of doors. If, in addition to these two atmospheric conditions, the air remains undisturbed, it becomes very disagreeable. We have all experienced such conditions out of doors as well as in rooms that are poorly ventilated.

Now certainly, in the case of out-of-doors air, the discomfort could not be due to carbon dioxid or to the so-called poisonous substances that may be present in close rooms. To prove that carbon dioxid had very little to do with making air uncomfortable or harmful for breathing, experiments like the following were tried: A number of persons were kept in a chamber in which the composition of the air could be controlled. When such air was kept free from carbon dioxid but was allowed to become warm and moist, the persons suffered great discomfort and were unable to carry on work effectively. When, on the other hand, the carbon dioxid was not removed, but the air was kept cool, the excess moisture removed, and the air kept in motion, those experimented upon felt perfectly comfortable and were able to do good work, and no ill effects from the excess of the carbon dioxid were apparent, unless the waste gas was allowed to increase to a degree far beyond that experienced under ordinary living conditions.

Evidently, then, that air of inhabited rooms may be suitable for breathing, it is necessary to change the air in

such a way as to keep it cooled and moistened to an agreeable extent and also to give it gentle movement. Now air from the great outdoors comes nearer to providing such conditions; hence we open the windows of our rooms to furnish the interchange of fresh air outside with the warmer, moister, and more quiet air inside and not necessarily to get rid of the carbon dioxid. It is possible by artificial means to so ventilate rooms that the air at all times, without regard to the conditions of the outer air, shall be agreeable on account of being of suitable temperature, of suitable degree of moisture, and in gentle motion. A window board arranged as in Fig. 131 prevents direct drafts and deflects the air current upward. Air can also circulate between the upper and the lower sashes, as indicated by the diagram.

Fig. 131

Summary

Lungs are the most essential breathing organs in man. *Air passages* serve to warm, moisten, and filter the air on its way to the lungs. The air passages are as follows: nasal passages, throat, larynx, windpipe, and bronchial tubes, which end in tiny elastic air sacs.

The *air sacs* are supplied with capillaries, through the walls of which oxygen and carbon dioxid diffuse. Arteries bring the blue blood containing carbon dioxid to the capillaries, and veins receive and carry the red blood with its cargo of oxygen to the left side of the heart, whence it is distributed to all parts of the body.

Air is forced out of the lungs by compression when the chest cavity is made smaller. When the chest cavity is made larger, the lungs at once expand, and then air enters.

Deep breathing, when brought about by vigorous work or play, develops and strengthens the muscles of the chest, increases the capacity of the lungs, and makes diseases of the lungs less likely.

Suffocation occurs when for any reason the supply of air to the lungs is cut off, for example, by choking, by gas, or by water. *Artificial respiration* is necessary whenever breathing movements have ceased through suffocation. It consists in making the chest cavity smaller by force, thus driving out air from the lungs. The elasticity of the chest walls and the lungs causes them to return to their former position, thus enlarging the chest and the lungs and so causing air to rush into the lungs.

The *carbon cycle* helps us understand how the percentages of oxygen and of carbon dioxid in the atmosphere remain about the same throughout the year. Green plants in daylight absorb the carbon dioxid given off by man, by animals, and by the combustion of fuels and then yield to the atmosphere an equal volume of oxygen needed in the respiration of living things.

Air in living rooms or where people congregate may be kept suitable for breathing by *ventilation.* Ventilation consists in exchanging the air that has been used with air from the outside. It may be either natural or forced ventilation. Air is most suitable for breathing purposes when it is cooled, moistened to an agreeable extent, and is in gentle motion. Air from the outside is usually more agreeable than air in enclosed spaces where people assemble because the air breathed out is too warm and too moist, and so the air of a room soon becomes stuffy and uncomfortable. Bedrooms or other living rooms may be ventilated by the opening of one or more windows at both top and bottom. Direct drafts should be avoided.

REVIEW QUESTIONS

1. Give two reasons why breathing in man is necessary.
2. What are the principal breathing organs in man, and where are they located?
3. Why are air passages necessary in man and the higher animals?
4. Name in order seven regions of the air passages.
5. State four adaptations found in the nose for preparing incoming air for the lungs.
6. State the function of the glottis, epiglottis, larynx, vocal cords, cilia, and bronchial tubes.
7. Describe the air sacs and show how they are adapted for interchange of gases.
8. Give an account of blood circulation to, through, and from the lungs.
9. Describe the processes of inhaling and exhaling.
10. What is the effect of exercise on breathing? How can you prove this?
11. What is the cause of choking, and how should cases of choking be treated?
12. Give three possible additional causes of suffocation. What are the first steps that should be taken in such cases?
13. Describe artificial respiration.
14. How is the composition of the air kept nearly constant from day to day?
15. How is a balanced aquarium maintained?
16. Describe the carbon cycle.
17. What were former theories as to the necessity of ventilation?
18. Give an account of the true theory of ventilation, and state how it may be put in practice at home or in a school building?

CHAPTER XIII

HOW CERTAIN LIVING THINGS CARRY ON REPRODUCTION

162. Why new living things are formed. Thus far we have considered the methods by which plants and animals, including human beings, live and carry on their individual work. It is a fact of common knowledge, however, that every living thing, after a longer or shorter period of life, dies.[1] Certain insects, for example, live in the adult stage for a few days at most (Fig. 132); elephants and giant tortoises (Fig. 133) may live for several hundred years; and some of the towering redwood trees (sequoias) of California (Fig. 16) began their life from two thousand to four thousand years ago. But the individual plant or animal, even though as long-lived as those we have just mentioned, finally dies. Hence, the most important part of biology, so far as the race is concerned, has to do with the methods by which the gift of life is passed on from one generation to another. This process is known as *reproduction*.

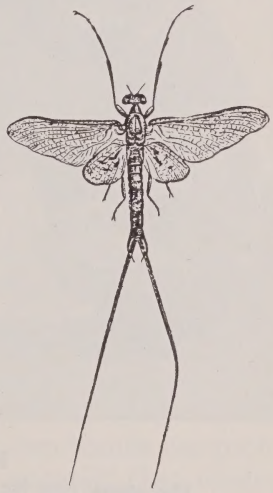
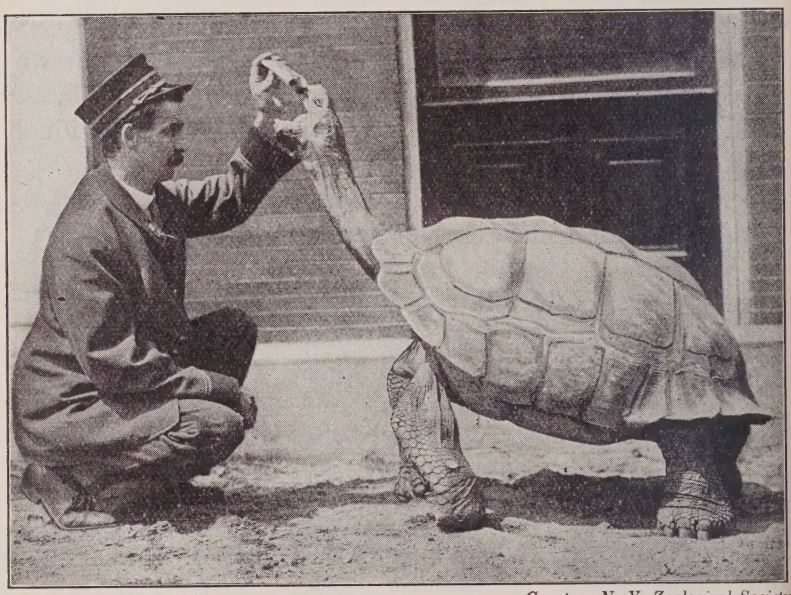


Fig. 132. — May fly
This insect lives only one day.

163. How the simplest animals reproduce. The simplest forms of plant and animal life are extremely minute and consist of only one cell. A multitude of these single-celled

[1] This is not strictly true in the case of one-celled plants and animals.

organisms may exist in a drop of stagnant water. If a drop of sediment from a stagnant pool is examined with a compound microscope, many kinds of microscopic plants and animals may be seen. Among them one may discover



Courtesy N. Y. Zoological Society

Fig. 133. — Giant tortoise
This animal from the Galapagos Islands is four hundred years old.

an irregular bit of protoplasm comprising a single cell. It may be moving about slowly by a flowing motion of the protoplasm. This one-celled animal is called an *amœba.*

The process of reproduction in such a simple animal is brought about by *cell division,* which is carried on in much the same way as that already described for the tissue cells of the higher plants and animals (**46**). This process consists of a division of the *cell nucleus,* followed by a division

of the cell body (Fig. 134). In the reproduction of the amœba, however, the two cells formed by division do not remain attached to each other, as do the tissue cells. Instead they separate into two distinct individuals, each having half of the living substance of the parent amœba.

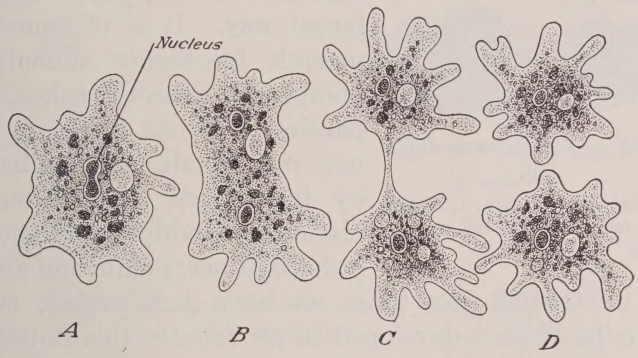


Fig. 134. — Amœba in successive stages of division
The dark spot is the nucleus.

Other single-celled animals reproduce in much the same way as does the amœba.

164. How the simplest plants reproduce. Anyone who has examined the shady north side of tree trunks has probably noticed a thin layer of green material that closely adheres to the bark. If a small amount of this green substance is mixed with water on a glass slide and examined with a compound microscope, tiny green cells that are more or less spherical in shape are seen. This single-celled plant is of the genus Pleurococcus. Like the amœba, it reproduces by division of the nucleus and cell body, and then cell walls of cellulose form between the "daughter cells" (Fig. 135). In Pleurococcus, however, the new cells formed by cell division often cling together for a time, and a *colony*

of cells is formed thereby. Like those of the amœbas the daughter cells of Pleurococcus, formed by division of the mother cell, are, so far as we know, exactly alike.

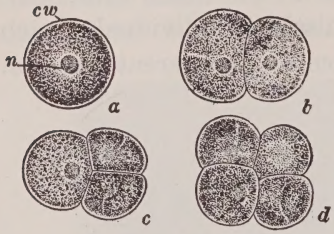


Fig. 135. — Pleurococcus dividing

a, single cell; *b*, two; *c*, three; and *d*, four cells; *cw*, cell wall; *n*, nucleus.

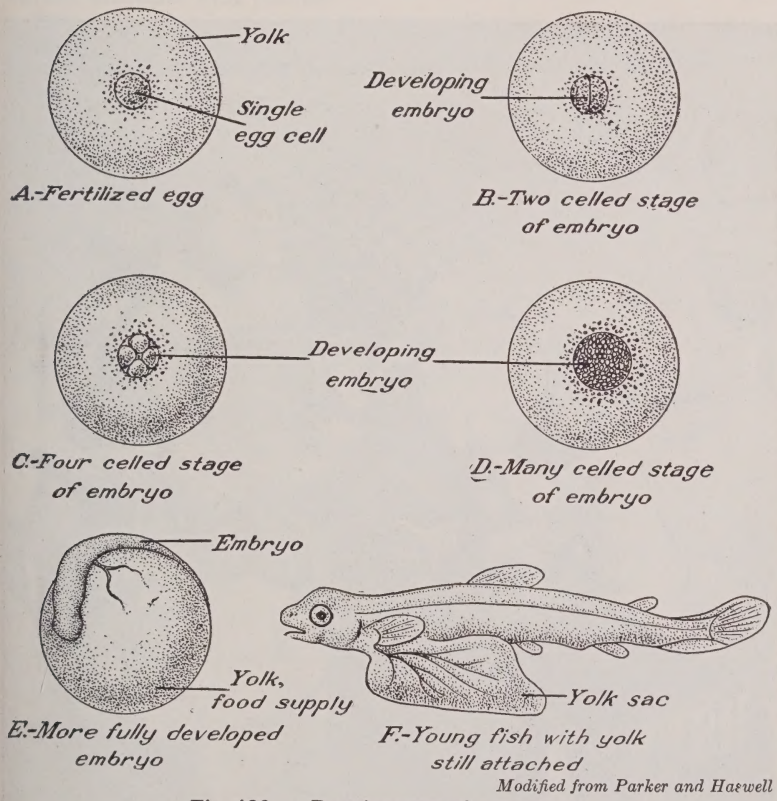
165. Why the higher plants and animals must reproduce in a different way. It is of course impossible for higher animals and plants (*e.g.* insects, fishes, cats, pansies, and oak trees) to form new individuals, as amœbas do, by the process of division into distinct individuals. Hence, in order that new plants and animals may be formed like those we have just named, certain organs have been developed to provide for this function of reproduction, just as there are separate organs for digestion and respiration. In the reproductive organs there are formed certain cells, which, after a complicated series of changes, form new individuals like the parent. We are now to study the method of reproduction as it is carried on by some of the many-celled animals and plants.

166. How young fishes are produced from eggs.[1] Anyone who has eaten the *roe* of shad has noticed that this part of the fish consists of countless tiny spherical objects called *eggs* (Fig. 141). All the other common animals with which we are familiar — insects, frogs, snakes, turtles, and birds — also produce eggs. Under natural conditions, after the eggs are given off into the water, a tiny fish is gradually formed

[1] The roe of fish should be shown in class, and separate eggs should be placed in small vials of preserving fluid. These specimens may then be used year after year. It is suggested also that, if the studies of reproduction are carried on in the spring, the eggs of frogs or toads be secured and placed in aquaria with green water plants and that their development into tadpoles be studied. (See Chapter XXIV.)

on the outer surface of the egg, and the rest of the egg material furnishes the necessary food for this process (Fig. 136).

When the animal has reached a certain stage of develop-



Modified from Parker and Haswell

Fig. 136. — Development of a trout egg

ment, it swims about in the water. Even now, however, some of this food material, known as *yolk*, remains attached to the under side of the developing fish (Fig. 136, *F*). This yolk is gradually absorbed by the young fish, and, by the

time it has disappeared, the young animal is able to secure its food supply from the surrounding water.

167. Why a fish egg alone can not develop into a fish. From our discussion thus far one might think that a fish

Fig. 137. — Securing eggs and sperm cells (milt) by gentle pressure

egg, if placed by itself in the water, would develop as we have described. That such is not the case, however,

can be shown readily if fully developed eggs are gently squeezed from the body of a fish into a dish of water. Such eggs, instead of forming fishes, soon die. We are now to study a most essential step in the production of all many-celled animals and plants.

Were we to visit a fish hatchery some day at the right season of the year, we would see men pressing the sides of the bodies of female fish, and thus forcing eggs out into the water from an opening situated on the under side of each animal (Fig. 137). The workers by gentle pressure also secure from male fish a milky material that is very different from the eggs. This is known as *milt*. A fish egg can develop into a fish only after one of the microscopic reproductive cells of the milt has united with it. Neither the egg cell nor the male cell in the milt can alone develop into a fish. When egg laying takes place naturally, this process is known as *spawning*.

168. What sperm cells are and what they do. What is the nature of the material that has been added to the egg cells which causes this marvelous transformation from a single egg cell into a fully developed fish? If we examine a drop of fresh milt under the high power of the compound microscope, we find innumerable microscopic cells that are swimming about. These are *sperm cells*. Each consists of a slightly enlarged portion known as the *headpiece*, which contains the *sperm nucleus*. The rest of the sperm cell consists of a slender portion called the *tailpiece*. By the quick lashing of this tailpiece a sperm cell swims rapidly through the water (Fig. 138).

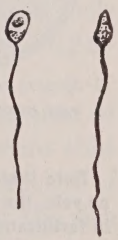


Fig. 138. — Sperm cells

A study under the microscope of a drop of water containing both eggs and milt shows that each egg is surrounded by a number of the extremely minute sperm cells

(Fig. 139, *A*), each of which is trying to force its way into the egg by means of its lashing tailpiece. A very careful examination often shows that the head of one of the sperm cells has been forced into one of the eggs and that the

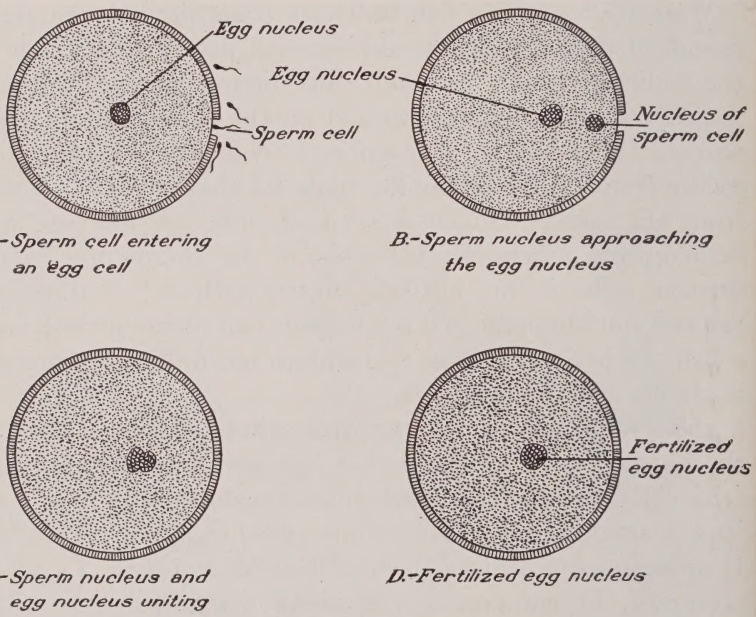


Fig. 139. — Fertilization of an egg

Note that the egg of this animal, unlike that of the fish, shown in Fig. 136, has no yolk, the food being stored in the egg cell. It shows however, the essential steps in fertilization referred to in the text.

tailpiece has dropped off. The sperm nucleus within the headpiece now moves toward the nucleus of the egg cell and increases somewhat in size. Soon the sperm nucleus and the egg nucleus combine to form a single nucleus (Fig. 139, *C*). *The union of sperm nucleus and egg nucleus is known as fertilization of the egg.*

169. How a fertilized fish egg develops into a fish. After fertilization has taken place, we see the egg nucleus dividing into halves. These halves move apart, and a cell membrane divides the single cell into two cells. Unlike the dividing amœba, however, the two cells remain attached to each other. Each of these cells soon divides in a similar way, and so four cells are formed (Fig. 136). The process of cell division continues until there is produced a large number of tiny cells, which are apparently all alike, but which really are beginning to differ from one another. By these successive steps a young animal known as a *fish embryo* is formed, which as yet bears little resemblance to the parent fish.

Presently, however, the head, trunk, tail, and other organs of the animal begin to appear (Fig. 136). When thin sections of any of these organs are studied under the microscope, we see rather striking differences in the cells of which they are composed. It is evident therefore that, when an egg develops, not only does a single fertilized egg cell produce many cells (*cell division*), but also that these cells gradually become different in form and function (*cell differentiation*).

170. What the organs concerned in the reproduction of the fish are. We now are ready to define certain terms that will be used frequently in the discussion of the process of reproduction. The organs commonly spoken of in the fish as the roe are known scientifically as the *ovaries* (Fig. 140) since in them are produced the eggs, or *ova* (from the Latin, meaning *eggs*). The sperm-producing organs, on the other hand, which are found only in the male, are called *spermaries*.

Under natural conditions, when eggs are fully developed, they pass out of the ovaries into the body cavity of the female fish. They then pass into the *egg tubes*, or *oviducts*

(Fig. 140), which convey them out of the body. In the male fish the sperm cells in a similar manner are conveyed from the spermaries by *sperm ducts* and so are discharged into the water in the region of the egg cells. When the nucleus of a sperm cell has combined with the nucleus of an egg

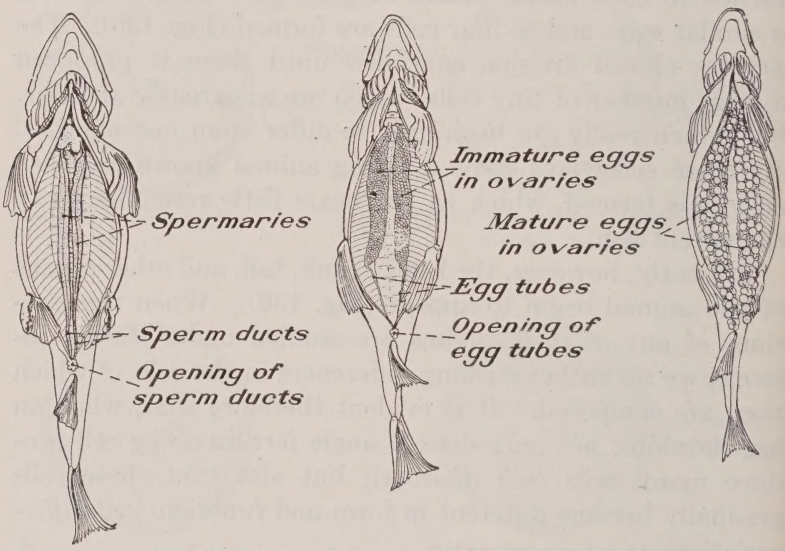


Fig. 140. — Organs of the male and the female fish

Reproductive organs of fishes. At the left, a male fish; at the right, two female fishes

cell, such a *fertilized egg cell* is ready to develop into a fish embryo in the manner already described (**169**).

171. How the young of fishes are fitted to survive. Most fishes, after the eggs are laid and fertilized, have no parental instinct and so take no care of their offspring. Indeed, a parent fish may even devour its own eggs or young. Since the eggs of fishes, after being deposited in the water, are exposed to so many dangers, relatively few of them will hatch, and still fewer of the young will reach maturity.

Hence, enormous numbers of eggs must be produced. In the ovaries of a perch, for example, over 18,000 eggs have been counted, and it is estimated that a large codfish (Fig. 227) may deposit 8,000,000 eggs at spawning time.

To the general rule that fishes take no care of their young, there is a marked exception in the sticklebacks, a group of rather small fishes found in fresh and salt water. The male stickleback constructs a rather elaborate nest by gluing together various materials, and in this nest several females generally deposit their eggs. The male then deposits sperm cells over the eggs, stays about the nest, and guards the eggs from possible enemies. The male also protects the young sticklebacks when hatched (Fig. 141). In the numerous American families of fresh-water bass and sunfish the parents zealously guard the eggs and the young. Among the frogs, toads, snakes, lizards, alligators, and turtles, however, the parent animals usually exercise no more parental care than most of the fishes do.[1]

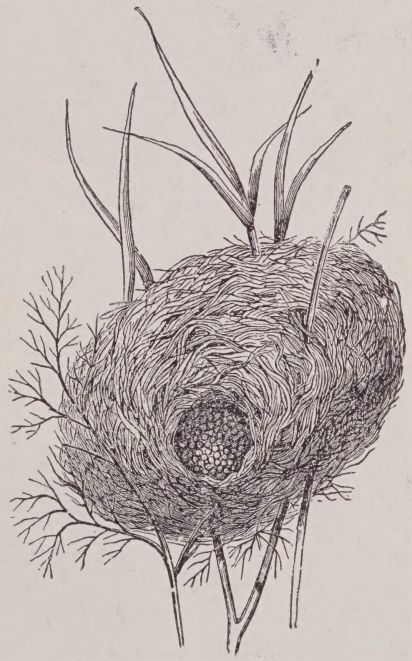


Fig. 141. — Nest of the stickleback
Note the eggs within the nest.

172. How the fern plant reproduces. Among the common kinds of ferns that are familiar to most people are the

[1] If it seems desirable, the reproduction of the bird may be studied at this time (288–291).

brake, the maidenhair, the rock fern, and the Boston fern, which is frequently cultivated in flowerpots. In any one of these ferns the leaflike parts above ground are known as *fronds* (Fig. 142). Each frond is usually divided and subdivided to form a more or less complicated (compound) leaf. The fronds grow upward and the roots downward from a swollen *underground stem*.

From Gager's Fundamentals of Botany

Fig. 142. — Clayton's fern

The leaves of the fern are known as fronds.

On the under surface of some of the subdivisions of fern fronds are little dots (Fig. 143), which are brown when fully developed. Each dot under the microscope is found to consist of several smaller objects known as *spore cases* (Fig. 144). When these tiny spore cases are ripe, they open, often with considerable force, and eject powdery particles, each consisting of a single cell known as a *spore* (Fig. 145, *A*), which has a thick wall.

When these spores fall upon the ground and when conditions are favorable, the single cell divides and forms two

cells (Fig. 145, *B*). By repeated cell division and by cell differentiation there is formed a tiny green heart-shaped plant known as a *prothallus* (Fig. 146), which has no resemblance to the parent fern that produced the spores. This tiny prothallus is anchored to the soil and supplied with water and mineral matter by means of tiny outgrowths somewhat like root hairs. Since the prothallus has chlorophyll, it can manufacture its own carbohydrates.

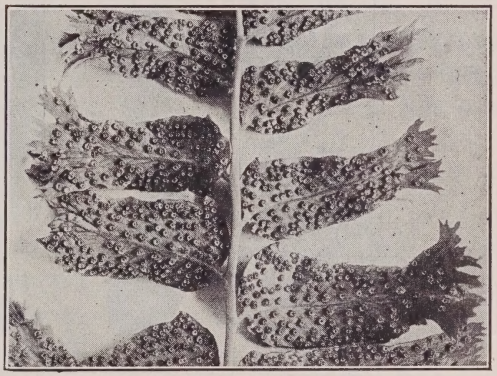
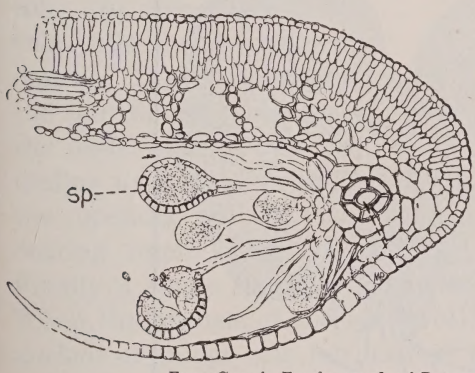


Fig. 143. — Under side of a fern leaf

Observe the numerous bodies, "dots," from which spores come.



From Gager's Fundamentals of Botany

Fig. 144. — Section of a fern leaf

Sp., spore case (sporangium) containing a large number of spores. The spore case below has opened and expelled a number of spores.

173. How egg cells and sperm cells are produced during the life history of a fern. On the under side of a prothallus in the region of the notch certain cells form elongated, somewhat flask-shaped organs (Fig. 146) that correspond in function to the ovaries of a fish. Within the enlarged region of each of these organs there is a single *egg cell* (Fig. 147).

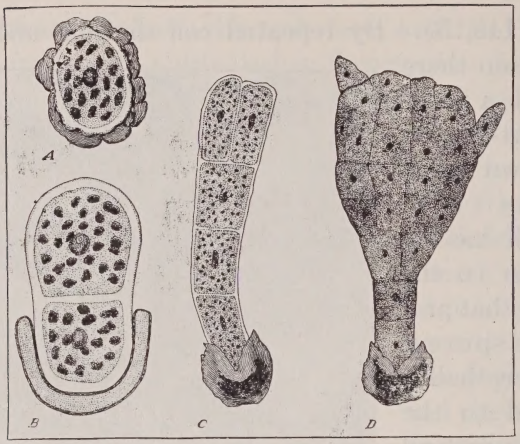


Fig. 145. — Development of a fern spore into a prothallus

A, section of a spore; *B*, first cell division of a spore; *C*, *D*, later stages of the prothallus formed by cell division.

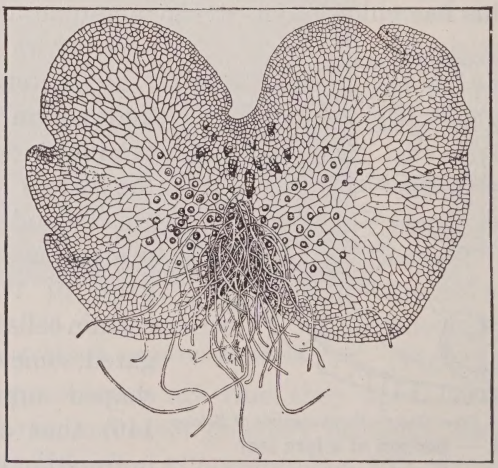


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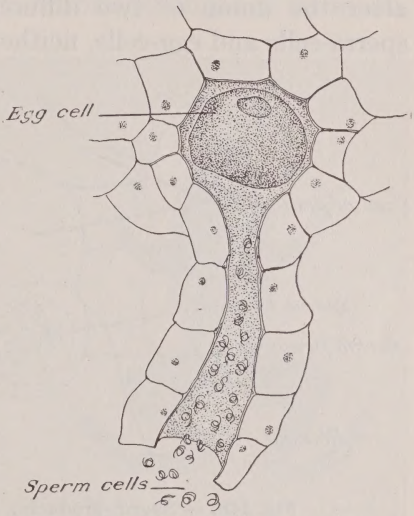
Fig. 146. — Fern prothallus

Observe the egg-producing organs (archegonia) near the notch; the sperm-producing organs (antheridia) near the rootlike structures.

Farther down from the notch on the prothallus and in the region of the rootlike bodies are other minute organs, spherical in appearance (Fig. 148), that correspond in function to the spermaries of a fish. In each of these is produced a large number of *sperm cells* (Fig. 148). Each sperm cell has many threadlike swimming organs. This tiny heart-shaped prothallus, therefore, unlike the fish, commonly has both the egg-producing and the sperm-producing organs in the same individual.



Redrawn from Gager's Fundamentals of Botany

Fig. 147. — Egg-producing organ of a fern prothallus

Sperm cells are entering the tube of the egg-producing organ on their way to the egg cell.

174. How fertilization and the development of the egg cell are accomplished during the life history of the fern. When the sperm cells are ripe, they escape from the sperm-producing organs. They swim through the thin film of moisture on the under side of the prothallus until they come to the opening in the egg-bearing organ (Fig. 147). Finally a single sperm cell reaches and enters the egg cell. When the nucleus of the sperm cell has combined with the nucleus of an egg cell, fertilization is completed.

The fertilized egg cell now divides, as in the egg of the fish, and thus a two-celled stage is reached. *Cell division* continues, just as in the fish. The cells change in their structure and functions (*cell differentiation*) and thus form the organs of a spore-bearing plant, like that described in **172**.

175. Why the union of sperm cell and egg cell is usually necessary in the reproduction of the higher plants and animals. Single-celled plants and animals, as we have seen, reproduce by cell division. But the many-celled organisms which we have studied form new individuals after the union of two different kinds of cells; namely, sperm-cells and egg-cells, neither of which is able to develop

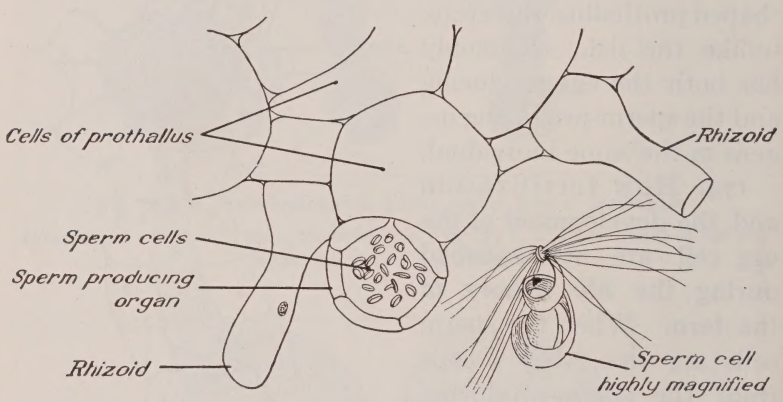


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Fig. 148. — Sperm-producing organ of a fern prothallus

Note the numerous slender swimming organs of the sperm cell. A rhizoid is a slender rootlike filament that functions as an absorptive organ.

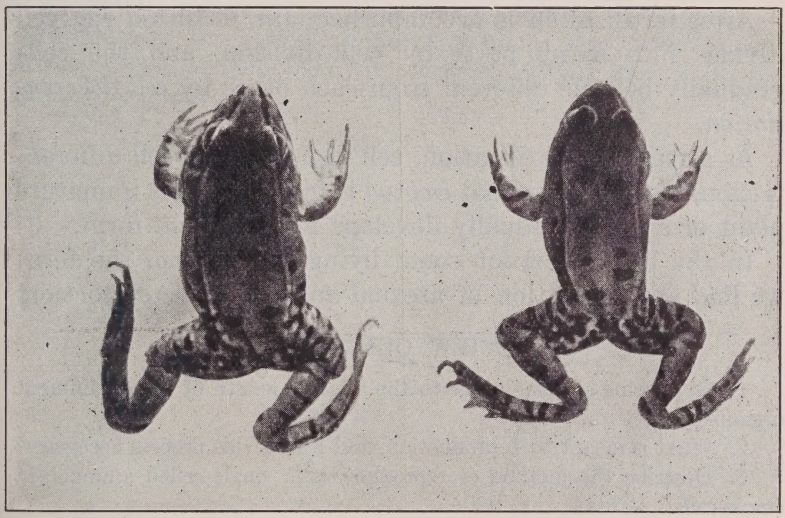
independently of each other. This kind of reproduction is called *sexual reproduction.*

It is interesting to note that Dr. Jacques Loeb of the Rockfeller Foundation, by a long series of investigations, has succeeded in causing the eggs of low forms of animal life (sea urchins and marine worms) to develop into normal larvæ by treating the eggs with certain chemicals.[1] Dr. Loeb also experimented with frogs' eggs by puncturing the membranes with a needle. Eggs treated in this way

[1] The chemical used was a weak solution of acetic acid (like that found in vinegar) followed by a treatment with concentrated sea water.

developed through the tadpole stage into adult frogs, both male and female. The frogs thus produced looked like normal frogs (Fig. 149).

These experiments show that the chemicals that were used or else the puncturing of the eggs caused the eggs to develop in a manner similar to normal fertilization by sperm



Courtesy Dr. Jacques Loeb

Fig. 149. — Frogs produced from unfertilized eggs

cells. It is evident, therefore, that the union of the sperm cell with the egg cell is needed to produce chemical or physical alterations in the egg, without which the eggs can not develop.

Summary

Reproduction is the process by which a living plant or animal forms new individuals like itself. This process is necessary since all many-celled living things finally die.

Single-celled plants and animals reproduce by *cell division.* In this process there is no distinction of sex, and so it is known as *asexual reproduction.*

In *sexual reproduction* a new individual is formed as a result of the union of a sperm, or male, cell with an egg, or female, cell. The union of the nucleus of a sperm cell with the nucleus of an egg cell is known as *fertilization.*

After fertilization is accomplished, the fertilized egg cell divides into many parts by cell division, and the cells gradually become different from each other by *cell differentiation.*

As a result of fertilization, cell division, and cell differentiation, a plant or animal *embryo* is formed. This immature plant or animal gradually develops into its *adult* form.

In the life history of some living things (*e.g.* the fern) we find an alternation of asexual and sexual reproduction.

REVIEW QUESTIONS

1. Give some statements as to the relative length of life of different organisms.
2. What is meant by reproduction, and why is this process necessary?
3. Describe the method of reproduction in single-celled animals; in single-celled plants.
4. Why is this simple method of reproduction impossible in the higher forms of animals and plants?
5. Describe the egg and sperm of a fish. What organs produce each of these kinds of reproductive cells?
6. How does the sperm cell reach the egg and the egg cell? What happens to the sperm cell after it reaches the egg cell?
7. Give an account of the methods of fish propagation used in a fish hatchery.
8. Describe the development of a young fish from a fertilized egg. Where is food material for development secured during this process? How are fishes fitted to survive?
9. Describe a common fern plant. Give an account of the formation of spores and of their germination to form a sexual plant.

10. Describe the inconspicuous stage (prothallus) of the fern plant with its organs for developing egg cells and sperm cells. How does fertilization take place? Describe the formation of the fern embryo.

11. Compare the adaptations for fertilization in the case of the fish and of the fern plant. How is the sperm adapted to reach the egg in the case of the fish?

12. In what respects are fertilization and development similar in a fish and in a fern plant, and how do they differ?

13. Write a summary of the life history of a fern.

14. Describe Dr. Loeb's experiments with the eggs of sea urchins, marine worms, and frogs. What conclusion do you draw as to the effect of fertilization?

CHAPTER XIV

HOW FLOWERING PLANTS REPRODUCE

176. How plants are produced from seeds. If we wished to get a new supply of bean, pea, corn, radish, or nasturtium plants, what steps would we take? Everyone who has cared for a garden knows that the soil would have to be loosened up properly and otherwise prepared and that seeds would have to be put in shallow furrows and covered with earth. From these seeds in due time would come plants of the same kind as those from which the seeds came.

In order that new maple or oak trees may be produced, it is likewise necessary that seeds of maple trees or of oak trees find their way into the earth. These seeds, if supplied with the proper amount of moisture and if favored by temperature, will sprout. Gradually a tiny plant (a seedling tree) will push its way up through the soil. This later will develop into a tree of the kind that produced the seed.[1]

Does a young plant exist ready formed in the seed, or is the young plant formed only after the seed is put into the ground? First, let us become familiar with the parts of a young plant by studying a seed that has begun to sprout.

EXERCISE 45

What parts of a bean plant are found in a sprouting bean seed? Laboratory study.

Materials: Soak bean seeds overnight and then cover them with moist sawdust. When the seeds have begun to sprout and to form roots, remove them and rinse off the sawdust. Keep the seedlings in covered pans with a small amount of water until they are needed for study.

[1] We shall discuss plant propagation more in detail in Chapter XV.

Carefully remove the outer covering (*seed coat*) from a sprouted bean seed. Detach one of the halves of the bean, known as a *seed leaf*, or *cotyledon*, and note the following parts within the seed coat: (*a*) the *two*

From Gager's Fundamentals of Botany

Fig. 150. — An elm tree

This giant elm grew from a seed like that shown in Fig. 161.

cotyledons; (*b*) the sprout, or *stem*, with a *root* and branching rootlets; and (*c*) two tiny folded *leaves* attached to the stem and lying between the cotyledons.

1. State what you have done to show the parts of the young bean plant.
2. Name, locate, and briefly describe each of the parts that you find.

EXERCISE 46

To show that a young plant is found in an unsprouted bean seed. Laboratory study.

Materials: Soak some bean seeds for twenty-four hours. Remove the seed coats, and from each carefully pull off one of the cotyledons.

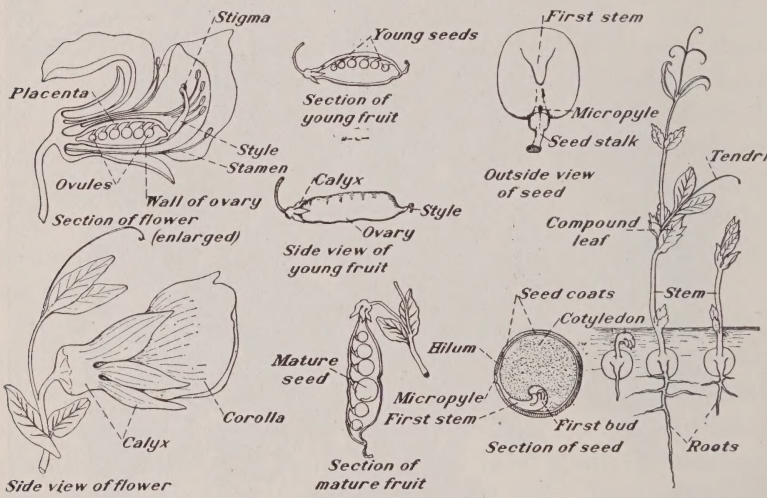


Fig. 151. — Development of a pea fruit, seed, and seedling

1. State what you have done.
2. Name three different kinds of parts, enumerated in Exercise 45 above, that you find present in the unsprouted bean seed.
3. Which of the organs of the young seedling (see Exercise 45) are not found in the seed?
4. NOTE (to be copied). All the parts found within the seed coats constitute a *bean embryo*, or young bean plant.

177. Where and when seeds are formed. Bean and pea seeds grow in *pods* (Fig. 151). Other seeds — apple, orange, lemon, grape, and pear — are found in *fruits* of the same name. Scientifically speaking, however, pea and bean

pods, tomatoes, watermelons, squashes, and peppers are just as truly fruits as are those we have named above, since all of them contain seeds.

A careful dissection of any seed will show the presence of an embryo plant (Fig. 165, E). The question then arises. How

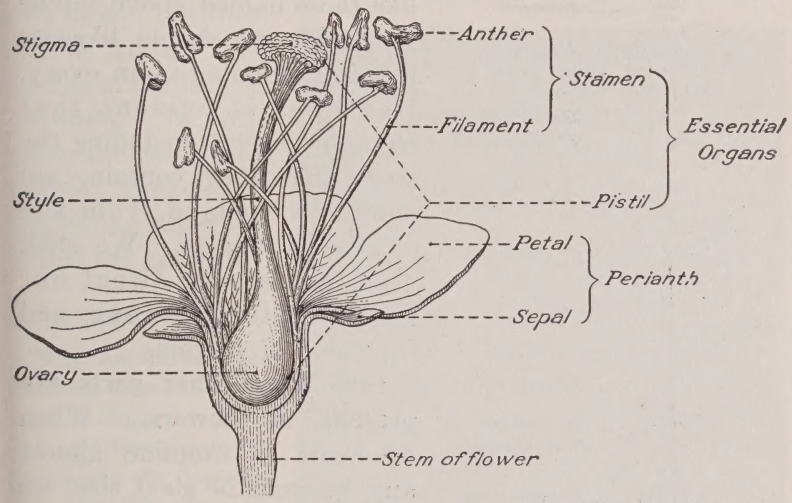
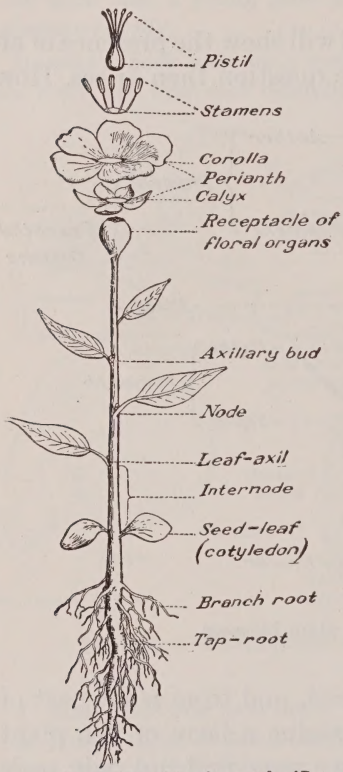


Fig. 152. — Parts of a plum blossom

are fruits with their seeds produced, and from what part of a plant do they come? If we examine a bean or pea plant that has blossomed (Fig. 151), we may find not only pods that are mature but also those in all stages, some even so small that they can hardly be seen with a hand lens. Indeed, if we dissect a bean or pea blossom, we find at the very center, a tiny object resembling a pod in appearance. This is the *ovary*. This organ contains tiny ovules which later develop into seeds.

At the free end of the ovary is usually a slender projection known as the *style*. At the top of the style is a slightly

enlarged portion called the stigma constitute the *pistil*.



From Gager's Fundamentals of Botany

Fig. 153. — **Parts of a flowering plant**
Note the four circles of organs of which the flower consists.

stigma. The ovary, style, and The ovary of a flower develops into a fruit that contains the seeds.

In the case of other fruits like those named above (apple or grape), we should likewise find its beginning in an ovary. Hence, it is evident that fruits in general, including the seeds that they contain, are somehow formed from the ovaries of flowers. We shall now, therefore, direct our study to the structure and functions of flowers.

178. What other parts are present in flowers. When we come to examine almost any blossom of good size, we easily find at its base an outer circle of rather small leaflike parts (Fig. 153). This circle as a whole is known as the *calyx* (from the Latin, meaning *cup*). Each of its subdivisions is called a *lobe* of the calyx; or if its parts are separate, each is called a *sepal*. Inside of the calyx is a second circle of parts usually brightly colored; this is the *corolla* (from the Latin, meaning a *small crown*), each of its parts being known as a *petal*. Within the corolla is a third circle of rather slender parts. Each is called a *stamen* and consists

of a threadlike stalk, the *filament* (from the Latin, meaning *thread*), and an enlarged top, the *anther*. In the anthers is produced a powdery substance known as *pollen*.

In case the two outer circles of a flower are much alike in form and color, as in the tulip, gladiolus, or Easter lily, all these leaflike parts taken together are called the *perianth*. In any case, the calyx and corolla spoken of together may be called the perianth.

From Gager's Fundamentals of Botany

Fig. 154. — Wood lily

The parts of the perianth in this flower are similar.

EXERCISE 47

What are the parts of the tulip flower? [1] Laboratory study.

1. On the outside of the flower are brightly colored leaflike parts arranged in two circles, making up the perianth.

a. Of how many parts does the perianth consist?

b. Draw (natural size) a side view of the flower. Label the perianth, the flower stalk, and the flower as a whole.

2. Inside of the perianth note the circle of stamens.

a. State the number and the location of the stamens.

b. Draw (natural size) one of the stamens. Label it and each of its parts.

3. At the center of the blossom note the triangular ovary and, above it, the three lobes of the stigma. The ovary and the stigma are the parts of the pistil, there being no style in this flower.

[1] These directions with some modifications will apply to flowers like the lily, gladiolus, or canna.

a. In what region of the flower is the pistil found?

b. Make a drawing (natural size) of the side view of the pistil. Label each of the parts of the pistil and the drawing as a whole.

4. We have found that the tulip flower consists of three different kinds of organs. Name in order of position, from the outside to the pistil in the center, the three kinds of organs, and give so far as you can the parts of each.

EXERCISE 48

What are the essential organs of a flower, and what is the use of each? Laboratory study.

Materials: Flowers of tulip, Easter lily, gladiolus, or canna.

1. Cut a thin cross section of the ovary, place it on a black background, and study it with a hand lens. The tiny white objects are *ovules* (Fig. 151). which develop into seeds.

a. Where are the ovules found?

b. Are the ovules attached to the outer wall of the ovary or to the central region? The region of attachment to the wall of the ovary of an ovule or a seed is known as a *placenta*.

c. Make a drawing ($\times$ 4) of the cross section of the ovary and of its contents. Label the wall of the ovary, ovules, placenta, and the drawing as a whole.

2. Study the ripened anthers in a blossom and find a powder (pollen) escaping from them.

a. Where are the pollen grains produced?

b. What is the color of the pollen you are studying?

3. Rub the finger tip or a camel's hair brush on a ripe anther from which pollen is being discharged. Now gently touch the surface of the stigma of the same flower or of another flower of the same kind.

a. This process we have just performed is known as *pollination*. Write a definition of pollination by stating what you have done.

b. State whether or not the pollen is held by the stigma; and if so, how. (Use a hand lens for this purpose.)

EXERCISE 49

What are the parts of the flower of the butter and eggs plant or of the garden snapdragon? Laboratory study.

Materials: Plants that have flowers and well-developed fruits.

1. Cut a thin cross section of a well-developed ovary (fruit). Place the section on a black surface and examine it with a hand lens.

a. Are the seeds many or few?

b. Are the seeds attached to the outer wall of the ovary or to the central region? The region of the ovary to which the seeds are attached is known as a *placenta.*

c. By the aid of a hand lens make a sketch (× 4) of the cross section of the ovary and its contents. Label the wall of the ovary, seeds, placenta, and the drawing as a whole.

2. Secure a fully opened blossom, grasp the colored parts near the top, and carefully pull them off, keeping these parts for further study.

a. In what region of the flower is the pistil found?

b. Note the ovary and a slender, white projection, the style, above it, at the top of which is an enlarged region, the stigma. The ovary, style, and stigma are parts of the pistil. Make a drawing (× 4) of the side view of a pistil and label each of the three parts of which it is composed.

c. Cut a thin cross section of the ovary, place it on a black surface, and study it with a magnifying glass. The tiny white objects are *ovules* which develop into seeds. Where are ovules found? How do ovules differ in size from seeds?

3. Open the two *lips* of the yellow and orange portion of the flower that you removed when studying the pistil. This is called the *corolla.*

a. Notice slender objects attached to the inner surface of the corolla. These are the *stamens.* How many stamens do you find, and how do they differ?

b. Each stamen consists of a slender stalk known as the filament and an enlarged top called the anther. Draw one of the stamens (× 4) and label the filament and anther.

c. Study the anthers in a blossom and find a powder escaping from each. This is *pollen.* By means of the finger transfer some of the pollen to a glass slide and examine it under the low power of a compound microscope. Where are pollen grains produced? Draw several of the pollen grains as they appear to you and label them.

4. At the base of the ovary notice small leaflike objects. They are the *sepals.* How many sepals do you find? Add the sepals to your drawing in 2 above and label them. The circle of sepals is known as the *calyx.*

5. We have found that the flower of butter and eggs consists of four different kinds of organs. Name in order of position, from the outside to the pistil in the center, the four kinds of organs and give so far as you can the parts of each. Make a drawing (natural size) of the side view of the open blossom and label parts.

NOTE. If flowers are studied in the autumn, the experiment in pollination should be performed at this time, using gladiolus or canna blossoms for this purpose. (See Exercise 48, 3.)

179. How a plant embryo is formed by the union of a sperm cell with an egg cell. In the many-celled forms which we studied in the preceding chapter — fish and fern — we found that the embryo was formed from a fertilized egg cell. Is this likewise true in a flowering plant? Our first problem is that of determining whether or not egg cells and sperm cells are present in such a plant. Microscopic study of the plant ovule shows that it consists of two outer coverings, or coats, made of cells and that within the fully developed ovule are other cells, one of which is an *egg cell* (Fig. 159). Hence we see that the ovule rather than the ovary corresponds in function to the ovary of a fish. In a similar way it has been proved that pollen grains (Fig. 155) have cells that correspond in function to the sperm cells of the fish and the fern. In some flowers the sperm cells may be formed while the pollen is in the anther. In other kinds of flowers the sperm cells do not develop until after the pollen reaches the stigma.

In each of the many-celled organisms we have studied, we found that, before development could take place, a sperm nucleus and an egg nucleus must unite. This union also occurs in a flowering plant. Let us now consider how it is possible for the sperm nucleus of a pollen grain to reach the egg nucleus of an ovule in the ovary. In the case of the fish and the fern, the sperm cell could swim to the egg cell.

Since stamens and pistils are surrounded by air and not by liquids and since pollen has no means of locomotion, some other method of transfer must be possible.

180. How pollen is carried to the pistil. In some flowers the filaments support the anthers in such a way that the pollen can be discharged readily upon the surface of the

From Transeau's General Botany

Fig. 155. — Pollen grains of various types
Note germination of pollen grains. *S*, sperm nuclei; *T*, tube nucleus.

stigma of the same flower when the stigmatic surface is ready to receive it. In cases like this, pollination is of course a simple process. Again, when pollen is light and powdery, it is readily blown about by the wind, as is the case especially in the inconspicuous flowers of the grasses and corn (Fig. 156). In these plants the stigmas are distinctly feathery or hairy in order to catch the flying pollen.

Many flowers, however, have pollen so situated that it can not fall upon the stigma; indeed, plants like the squash

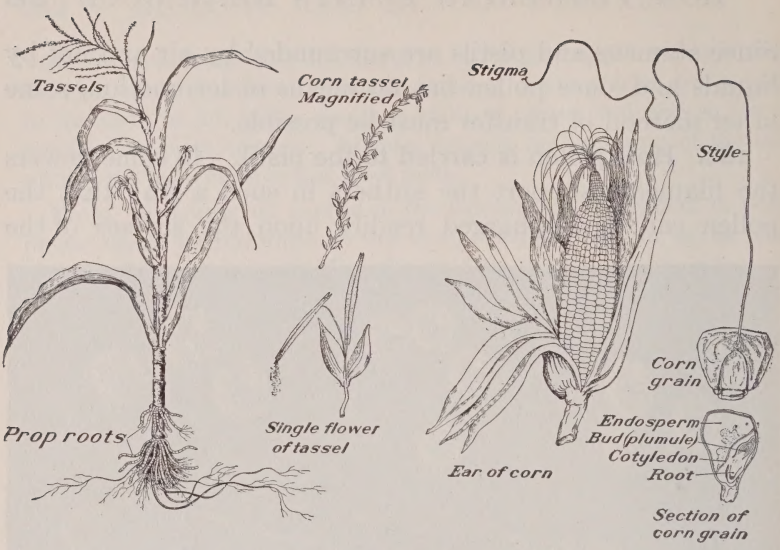


Fig. 156. — Reproduction in a corn plant

Observe the grains on the ears (egg-producing organs) and the anthers of the tassels (sperm-producing organs).

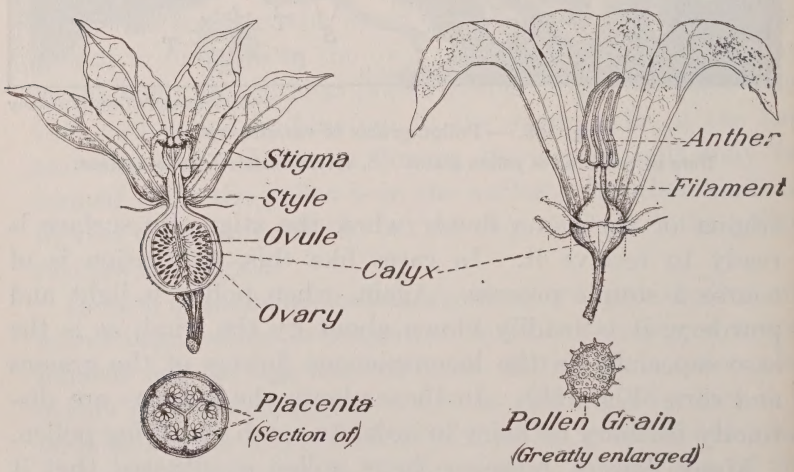


Fig. 157. — Blossoms of the squash plant

At left, ovule-producing flower; at right, pollen-producing flower.

have two kinds of flowers: one having stamens and no pistil; the other a pistil and no stamens (Fig. 157). In other kinds of plants the pollen may ripen at a time when the stigma is not ready to receive it; again, the pollen may be too sticky to be easily detached and carried by the wind. In those cases there must be some agency of transfer other than gravity or the wind.

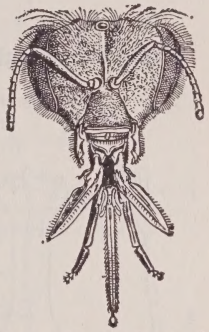


Fig. 158. — Head of a honeybee

When the blossoms of fruit trees or of clover plants open, they frequently are visited by bees. If we watch the bees, we shall see them thrusting their sucking tongues deep into the fragrant blossoms in search of their food. As the bees push their way into the flowers, their hairy tongues (Fig. 158) and heads become coated with the sticky pollen that is discharged from the anthers of the stamens. When the insects fly away to other blossoms, pollen is carried along and some of it will be left on the stigma of the projecting pistil. Butterflies, moths, and some other kinds of insects also carry pollen, but honeybees and bumblebees are far more important in pollination.

Most flowers that are pollinated by insects are distinguished by colors and odors that are believed to attract the insects. In these cases the insects are repaid for their visits by securing a sweet liquid, known as nectar, which is secreted in *nectar glands*. Bees use this *nectar* in making honey. Flowers, the pollen of which is carried by the wind, such as these of corn and grasses, have small inconspicuous flowers that lack bright colors and sweet odors.

Pollination may be defined as the transfer of pollen from the anther of a stamen to the stigma of a pistil. If the transfer

is made from the stamen to the pistil in the same flower or, more precisely, to the pistil of another flower on the same plant, the process is known as *self-pollination.* In *cross-pollination* the pollen is carried from the anther of one flower to the stigma of another flower of the same kind but on a different plant.

EXERCISE 50

What changes take place in the pollen when it reaches the stigma? Laboratory demonstration.

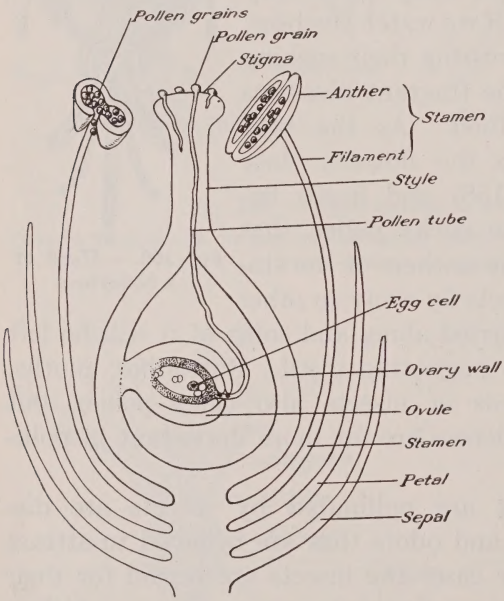


Fig. 159. — Fertilization of an egg cell in an ovule
Trace the course of the fertilizing nucleus of a pollen grain from the anther to the ovule.

Material: Ripe stigmas of flowers such as Easter lily, tulip, canna, gladiolus, or tiger lily, that have been pollinated at least six to twelve hours.

1. Cut off a very thin slice *horizontally* from the surface of the stigma, place it on a glass slide with several drops of water, and mash the section thoroughly with a knife blade. Cover with a cover glass and examine with the low power of the compound microscope. Find a pollen grain that has begun to form a projection, that is, a *pollen tube.*

2. Make a drawing of various stages of the germinating pollen and an unsprouted pollen grain, labeling the pollen grain, pollen tube, and unsprouted pollen.

181. How does a sperm nucleus reach and fertilize an egg cell? After pollination is accomplished, pollen grains

are held to the stigma by hairs or by a sticky secretion or by both. From the stigma the pollen grains absorb food substances and a pollen tube begins to grow from each grain (Fig. 159). Each pollen tube makes its way downward between the cells of the stigma and style until it reaches the small opening in an ovule. This opening is the *micropyle* (from the Greek, meaning *small gate*). After entering the micropyle, the tip of the tube breaks open and the protoplasmic material within the tube, which includes two sperm nuclei, is forced into the ovule. One of the sperm nuclei finally reaches and unites with the nucleus of the egg cell. Thus fertilization of the egg cell is accomplished (Fig. 160).

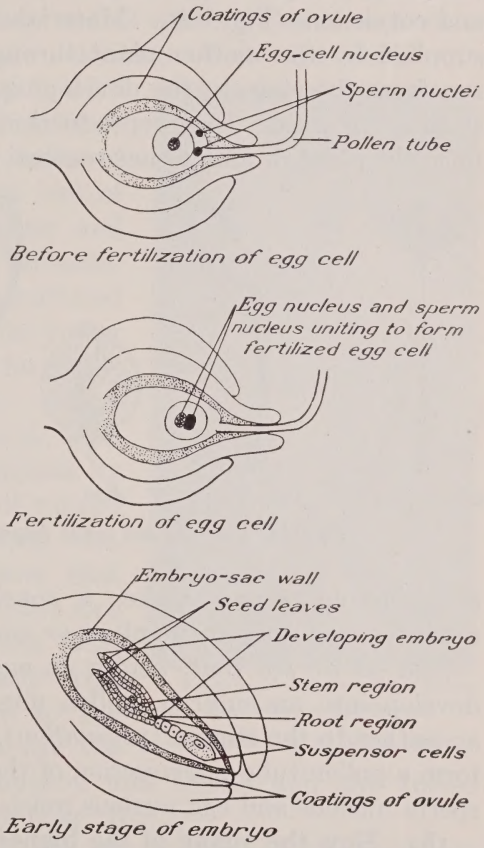


Fig. 160. — Formation of a plant embryo

182. How a fertilized egg cell develops into a plant embryo. The egg cell after fertilization divides in half in a way similar to cell division in the egg of a fish or in a fern, and division continues until many cells are formed. The

cells become different in structure and function (*cell differentiation*) and gradually form the parts of the tiny plant, or embryo, which we found in the seed; namely, stem, bud, and cotyledons (Fig. 160). Materials for further growth are supplied by the mother plant through the sap tubes that run from the stem to the developing embryo. In all these studies we notice that reproduction does not take place until the plant or animal has reached its maturity, since the

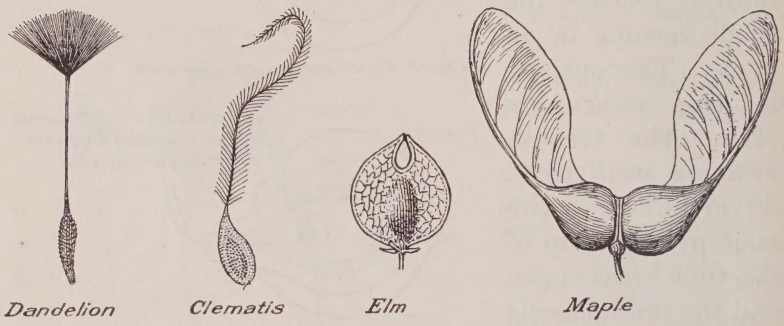


Fig. 161. — Fruits and seeds dispersed by wind

reproductive process makes a considerable draft on the nutritive resources of the plant or animal.

And so we see that, before an egg cell of an ovule can develop into an embryo, pollen must be transferred from an anther to the stigma (*pollination*), the pollen grain must form a pollen tube (*germination* of the pollen grain), and the sperm nucleus and egg nucleus must unite (*fertilization*).

183. How the young of the higher seed plants are fitted to survive.[1] The embryos of flowering plants are not only supplied directly with food materials during the early stages of development but are also given a store of sufficient

[1] Before assigning this section for study, the teacher should so far as possible, demonstrate the various methods of seed protection and dispersal and stimulate pupils to do as much field work as they can profitably undertake.

food in the seed, either in the embryo itself, as in the bean or pea (Fig. 151), or around it, as in the corn grain (Fig. 156). To a certain extent, also, the growing embryo is protected within the mother plant and is provided with seed coats that later may become relatively thick and hard.

If the seeds of plants were to start their germination close to the parent plant, most of them would perish from lack of water and mineral matter and sunlight. Hence it is advantageous for seeds to be scattered rather widely so that the young plants may secure favorable conditions for growth. Many kinds of seeds, or fruits, seem specially fitted for dispersal by the wind. Examples of winged fruits (*i.e.* fruits provided with broad and thin surfaces that are blown by the wind) are those of the maple, elm (Fig. 161), and linden. Some with tufts of hair attached to the upper end of a stalk are the tiny fruits of the dandelion and thistle and the tufted seeds of the milkweed (Fig. 162).

From Gager's Fundamentals of Botany

Fig. 162. — Milkweed

Note the pods of tufted seeds.

Other common fruits like the cocklebur, burdock, and other "sticktights" (Fig. 163) have sharp hooks, or barbs, which catch in the hair of animals and so either the seeds, or fruits, are often carried for some distance from the parent plant, before they become detached.

Still another method of seed dispersal is that seen in

fleshy fruits like the brilliant cherry and berries of various kinds. Birds are attracted by the bright colors of these fruits when they become ripe. In the case of fruits like cherries, the birds eat the fleshy pulp and drop the hard pits (cherry seeds). In the case of raspberries and blackberries the seeds are so small that they are eaten with the pulp and being hard and indigestible they are dispersed with the other body wastes. Squirrels, too, in their attempts to hoard nuts for a winter supply, often bury them in the

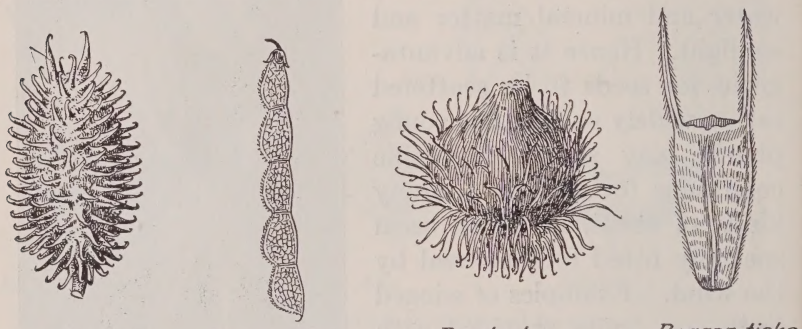


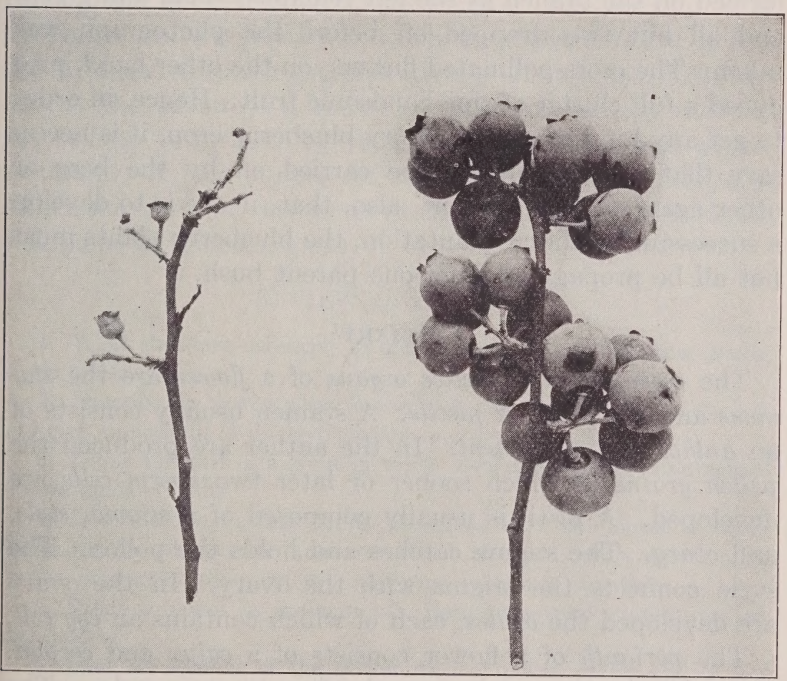
Fig. 163. — Fruits and seeds dispersed by animals

ground or drop them before reaching the hollow trees selected for storage. Some tiny seeds stick to the feet of birds and other animals. Still other fruits or seeds like the cocoanuts are carried for some distance on the surface of water.

184. How do we know that better fruits often result from cross-pollination than from self-pollination? In Fig. 164 is a striking proof of the advantage of cross-pollination over self-pollination in blueberries. This experiment was one of many carried on by Dr. Frederick V. Coville, Botanist of the United States Department of Agriculture, Washington, in connection with his work on the cultivation of blueberries. In the picture are shown two twigs of a blueberry bush,

both of which had the same number of flowers. Both grew on the same bush and in equally good situations. Both of the twigs were photographed, natural size, on the same day.

Before the flowers were ready for pollination the stamens were removed from each in order to prevent self-pollina-



Courtesy Dr. Frederick V. Coville

Fig. 164. — Self- and cross-pollination in blueberries

tion. The pistils of the flowers on the left-hand side of the picture were then carefully supplied with pollen from flowers on the same bush (in other words, self-pollination was carried on). Each of the flowers on the twig at the right side of the picture was treated with pollen taken from flowers on another bush (cross-pollination). All these experiments

were performed in a greenhouse where insects could not have access to the flowers. After pollination the fruits were allowed to develop.

The result, as you can see, is most striking. The self-pollinated pistils produced no ripe fruit. All the fruit that formed on the branch at the left remained small and green, and all but two dropped off before the photograph was taken. The cross-pollinated flowers, on the other hand, produced a full cluster of ripe handsome fruit. Hence, in order to get any kind of a satisfactory blueberry crop, it is necessary that cross-pollination be carried on by the bees or other agency. It is evident, also, that, if one is to develop a successful blueberry plantation, the blueberry plants must not all be propagated from one parent bush.

Summary[1]

The *essential reproductive organs* of a *flower* are the *stamens* and the *pistil* or *pistils*. A stamen usually consists of an *anther* and a *filament*. In the anther are produced the *pollen grains* in which sooner or later two *sperm cells* are developed. A pistil is usually composed of a *stigma*, *style*, and *ovary*. The stigma catches and holds the pollen. The style connects the stigma with the ovary. In the ovary are developed the *ovules*, each of which contains an *egg cell*.

The *perianth* of a flower consists of a *calyx* and *corolla*. The calyx is composed of *sepals* often green in color. The corolla is composed of *petals* which are usually bright-colored. The principal use of the corolla is to attract insects and so bring about *cross-pollination*.

The processes necessary for *seed formation* are *pollination*, *germination of pollen*, *fertilization of the egg cell*, *formation of an embryo by cell division* and *cell differentiation*, and the

[1] For a general summary of reproduction in living things see Chapter XXI.

formation of a food supply. Pollination is the transfer of pollen from the anther to the stigma. If the pollen is transferred to a stigma of the same flower or to the stigma of another flower on the same plant, it is called *self-pollination.* If the pollen is transferred to the stigma of a flower on another plant it is called *cross-pollination.* By *germination of the pollen a tube is formed* in which the *sperm cells are carried* down to and through the micropyle of the ovule. *Fertilization* is the *union* of a *sperm nucleus* with an *egg nucleus.* An *embryo* is formed by repeated *cell division* and *differentiation.* A *food supply* for the growth of the embryo is either *stored in the embryo* as in the bean seed or *outside the embryo* as in the corn grain.

REVIEW QUESTIONS

1. What steps are necessary to secure vegetables or flowering plants in our gardens?
2. Describe the young plant (embryo) in some seed you have studied and give an account of its development into a seedling.
3. Name the part of a plant in which seeds are formed. Enumerate several kinds of fruits.
4. Describe the various kinds of organs that are found in some flower with which you are familiar. Which of these organs are essential for the production of an embryo, and what is the use of each?
5. What is meant by pollination? Describe several adaptations for this process.
6. Give an account of the germination of pollen grains and of the fertilization of the egg cell.
7. Describe the development of an egg cell into a plant embryo.
8. How is the plant embryo supplied with food during the early stages of germination?
9. Why is it necessary that seeds be carried away from the mother plant?
10. Describe several methods by which seed dispersal is accomplished.

CHAPTER XV

HOW PLANT PROPAGATION IS CARRIED ON

I. Seeds and Their Development into Plants

EXERCISE 51

Study of the bean seed and the development of the bean seedling. Laboratory study.

Materials: Dry bean seeds and seeds that have been soaked for twenty-four hours; sprouted bean seeds and seedlings grown as follows: To secure early stages, cover seeds that have been soaked for twenty-four hours with moist sawdust, and allow them to stand in a warm place for two or three days; for older stages of bean seedlings, plant soaked seeds in boxes containing a mixture of moist sawdust and earth. If some of these boxes are put in a warm place and others in a cool place, all stages may be obtained in two to four weeks.

1. What difference do you note in the size of the dry and soaked seed? How do you account for this difference?

2. On one edge of a soaked seed find a *scar* (the *hilum*), which marks the place where the bean was attached to a small stem that connected it to the pod. Locate the hilum and state how it was caused.

3. Pinch a soaked seed and note an opening near the hilum through which water is forced from the seed. This is the *micropyle*, the opening through which the pollen tube entered the ovule.

a. Describe the position and appearance of the micropyle.

b. What is one use of the micropyle during the development of the seed (181)?

c. What do you notice at the end of the hilum opposite the micropyle?

4. Make a sketch of the bean seed ($\times$ 2), showing the surface where the scar is found, the outline of this edge of the bean, the elevation, the hilum, and the micropyle. Label each of these parts and the drawing as a whole. Draw also a side view of the bean seed, showing as many parts as possible, and label them.

5. Carefully remove the *seed coat* and one *cotyledon*. Place the cotyledon at one side but close to its point of attachment to the small stem (also known as *hypocotyl*). Make a drawing ($\times$ 2) showing the parts of the bean embryo. Label the two seed leaves, or cotyledons, the first stem, or hypocotyl, and the first bud, or *plumule*. Label the drawing as a whole.

6. Examine a bean seed that has just begun to sprout.

a. Name the part of the bean embryo that first breaks through the seed coats.

b. Make a drawing ($\times$ 4) showing the side view of the sprouted seed. Label all parts.

7. Look at a pot of young seedlings that are just pushing their way above the surface of the soil or sawdust.

a. What part of the embryo first appears above ground?

b. What is the shape of this part?

8. Study at this stage a seedling from which one cotyledon has been removed.

a. Describe the changes that take place in each part of the embryo after the seed begins to sprout.

b. Describe the position and the appearance of the main root and of its branches at this stage.

c. Make a drawing (natural size) of a seedling at this stage and show by a horizontal line the ground level. Label each part.

9. Study a well-developed seedling, comparing it with the stages already drawn, and answer the following questions:

a. What changes in the size of the cotyledons do you note as the seedling grows older? Most of the food for the early development of the seedling is furnished by the cotyledons; suggest, therefore, the cause of the change in size of the cotyledons, which you have noted.

b. What parts of the developing embryo change in color during germination; how do they change?

c. What parts of the oldest seedling have developed from the plumule?

10. Draw the oldest stage of the bean seedling and label the main, or *primary*, root, root branches, or *secondary roots*, ground level, cotyledons (or scar left by cotyledons), hypocotyl, stem above cotyledons (*epicotyl*), leaves of plumule, and terminal bud.

11. Compare the various stages of the sprouting bean with similar stages of the pea (Fig. 151). State likenesses and differences.

EXERCISE 52

Study of the corn seedling and its development from the corn grain. Laboratory study.

Materials: Dry and soaked corn grains; seedlings of various sizes grown as described above for the bean seedling. For our purpose corn grains should be planted with the pointed end down.

The structure of the corn grain and the development of the corn embryo can be understood much more easily if the study of the corn seedling is made first and later that of the corn grain.

A. Seedling just breaking ground.

1. Examine a pot of seedlings that are just pushing their way through the soil or sawdust and study a seedling at this stage. All the parts of the seedling above the corn grain have developed from the first bud, or *plumule*.

a. What is the shape of the part that first breaks through the soil?

b. Look for the *sheath leaf* surrounding the unfolding leaves and trace it down to the ridge around the stem from which it springs. How does this sheath, or first leaf of the plumule, differ from the unfolding leaves? What is its probable use?

2. Observe the scar on the grain that shows where it was fastened to the cob and note the shape of the grain at its opposite end. Does the plumule develop from the blunt end or the pointed end?

3. Make a sketch of the seedling ($\times$ 2) and label the grain of corn, scar where grain was attached to the cob, stem of plumule, sheath leaf, unfolding leaf, main root, rootlets, and soil line.

B. Corn grain just sprouting.

1. Examine a corn grain that has just sprouted. Recall to mind the end of the grain from which the main root grew. (If you are not sure, look at your drawing or, better yet, at the seedling.)

a. What part of the little corn plant breaks through the covering first?

b. What other part of the embryo shows signs of growth?

2. Remove the thin covering from the grain and observe an oval body embedded in the corn grain. This is the little corn plant, or embryo. How does the embryo differ in color from the rest of the grain?

3. The oval-shaped body from which the root and plumule seem to spring in the grain of corn is the cotyledon. The remainder of the grain is food material (*endosperm*) for the development of the embryo. Make

a sketch (× 2) of the seedling at this stage and label a single cotyledon, plumule, endosperm, and main root.

C. Corn grain.

1. Very carefully scrape away a little of the surface of the cotyledon of a dry or soaked grain till the other parts of the plant embryo come into view. Identify the plumule and main root.

Sketch the corn grain and label the cotyledon, plumule, tiny root, and endosperm.

2. Cut a corn grain in such a way as to divide the embryo and endosperm lengthwise in half. Put one half in an iodine solution. Where in the corn grain is starch present? Where is it absent?

D. Corn seedling well advanced.

1. What changes in the roots have taken place during the development of the seedling? What changes in the plumule?

2. How does the veining of the leaves in the corn plant differ from that in the leaves of the bean plant?

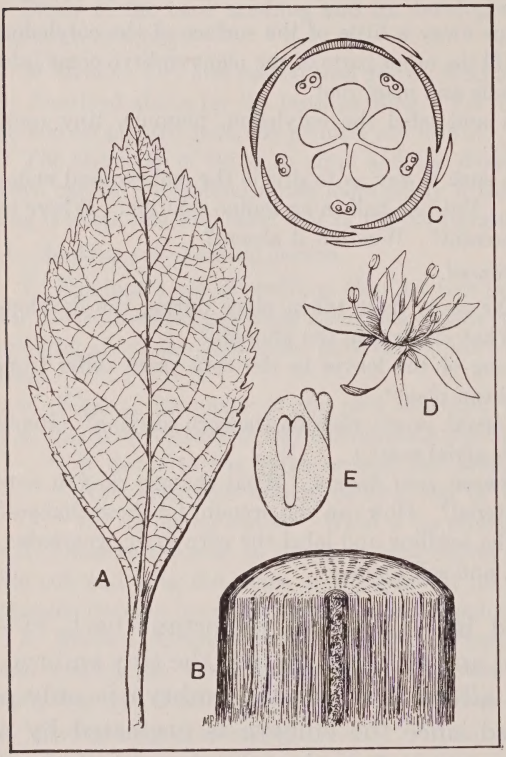
3. Where do you find *aërial*, or *air*, *roots* on the corn seedling? (Roots growing above ground are aërial roots.)

4. Pinch the grain between your fingers. What changes do you note in the amount of food material? How can you account for these changes?

5. Make a sketch of the seedling and label the corn grain, cotyledon, stem, leaves, aërial roots, and soil roots.

185. What a seed is. The most important part, evidently, of a bean seed and of a corn grain is the tiny embryo. This is also true of all seeds. But the embryo is only a part of the bean seed since the embryo is protected by a covering, which is composed of coatings (*seed coats*), derived from the ovule (Fig. 160). Also the cotyledons of the bean embryo are much enlarged to hold the food for the early growth of the tiny plant. Likewise the corn grain is provided with a store of food inside the single cotyledon of the embryo and a much larger store of food outside the embryo in the endosperm (Fig. 156). We may therefore say that a *seed is an embryo plant provided with food and protected by coatings.*

186. How seeds differ. First, seeds vary greatly in size. As an illustration of the wide range of difference in this respect we may compare the tiny bird seed and the coconut. Second, seeds differ with reference to each of the three parts named above: embryo, food supply, and coatings.



From Gager's Fundamentals of Botany

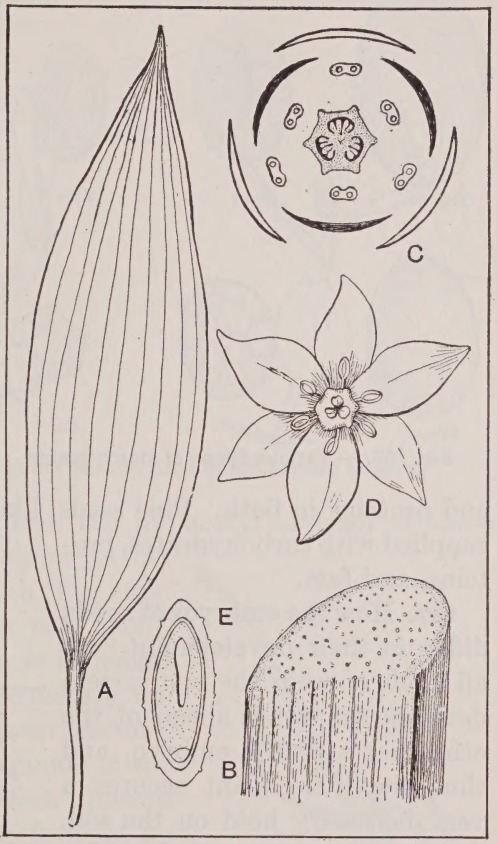
Fig. 165. — Dicotyledonous plant

A, leaf, net-veined; B, stem with wood arranged in annual rings; C, diagram of cross section of a flower (the parts in 5's); D, flower; E, section of a seed having an embryo with two cotyledons.

The bean embryo has two cotyledons, and the corn has one. Some embryos, however, have more than two cotyledons; the pine tree is an example. Seed plants have been classified according to the number of the cotyledons found in the embryo. Hence we have all plants in which the embryos develop two cotyledons grouped together. These plants are called *dicotyledons* (Fig. 165). Beans, peas, squashes, and castor beans are examples of dicotyledons. The plants like the corn in which the embryos have only one cotyledon are called *monocotyledons* (Fig. 166). Examples of monocoty-

ledons are the grasses, to which the corn belongs, all members of the lily family, and palm trees. The pines, hemlocks, spruces, and firs may be called *polycotyledons*. The embryos of seeds differ in structure in other respects, but the number of cotyledons furnishes the most striking variation.

The *location of food stored* furnishes another point of difference. Thus bean, pea, and squash seeds have the food stored in the cotyledons; that is, in the embryo. This is also true of a large number of kinds of seeds. In the corn, however, the greater amount of food is found outside the embryo. In the castor bean and pine seeds practically all the food is stored outside the embryo, the cotyledons being very thin in the castor bean and slender in the pine seed.



From Gager's Fundamentals of Botany

Fig. 166. — Monocotyledonous plant

A, leaf, parallel-veined; B, stem with woody bundles scattered through the pith; C, diagram of cross section of a flower (the parts in 3's); D, flower; E, section of a seed having an embryo with one cotyledon.

The *relative amounts of the food substances* also vary somewhat. Thus beans and peas are rich in both proteins and starch but contain extremely small percentages of fat. Castor beans are rich in oils and proteins and contain practically no carbohydrates. Corn grains have a rich supply of starch in the endosperm, a good proportion of fat in the cotyledons, and proteins in both. Pine seeds, like corn grains, are well supplied with carbohydrates, proteins, and fats.

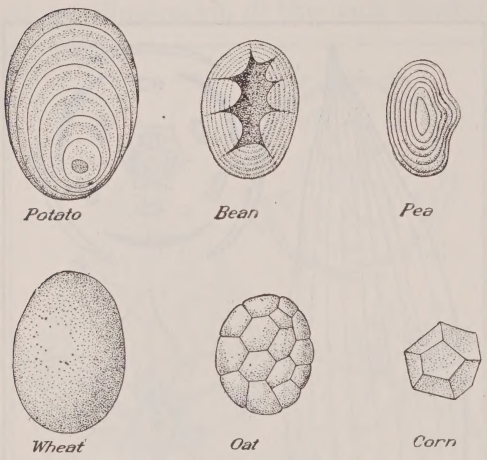


Fig. 167. — Various forms of starch grains

187. How the embryos of seeds differ in their development. In all kinds of seeds the root system develops somewhat ahead of the other parts of the embryo, and thus the little plant secures a very necessary hold on the soil. In the development of the other parts of the embryo there is considerable variation. In the bean, castor bean (Fig. 168), pine, and squash embryos the hypocotyls elongate quite rapidly and carry with them, therefore, the cotyledons which enclose the developing plumule. On

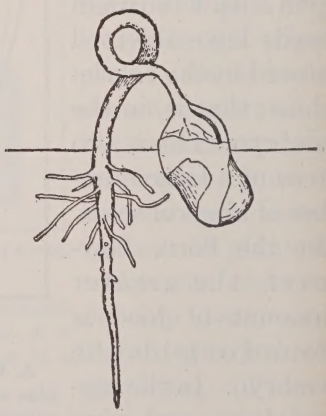


Fig. 168. — Castor bean

account of the weight and the size of the cotyledons in the bean and the squash and the weight of the endosperm of

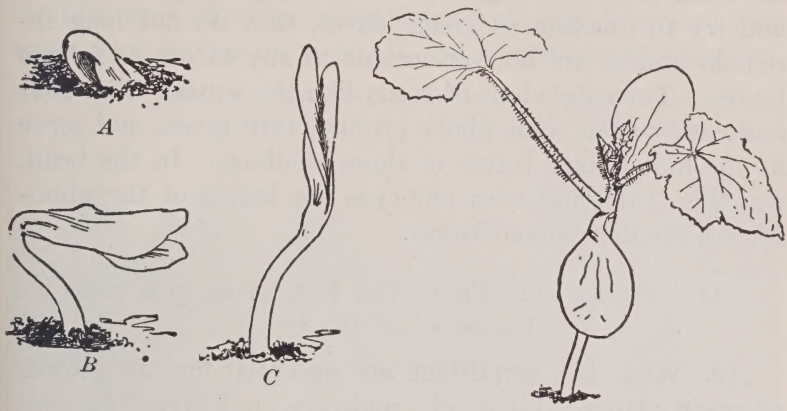


Fig. 169. — Stages in the development of the squash seedling

the pine and castor bean the hypocotyl of each of these embryos is obliged to elbow its way out in the form of an arch (Fig. 169). The hypocotyls of the pea, Windsor bean, and corn grow in length scarcely at all. Consequently the cotyledons remain under ground, and the stem of the plumule in the pea and Windsor bean pushes through the soil in the form of an arch. In corn, oats, and wheat embryos (Fig. 170) the plumule is protected by a sheath leaf, and the whole tapers to a sharp point. Such plumules come out of the ground straight and not in the form of an arch.

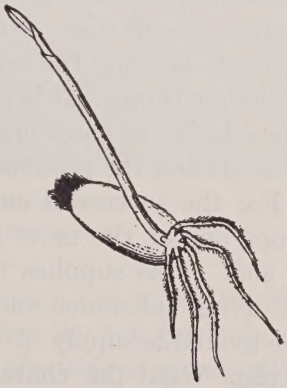


Fig. 170. — Wheat seedling

The cotyledons of embryos like those of corn, pea, and

Windsor bean can not, of course, serve as foliage leaves at all since they remain under ground. The cotyledons of the bean come above ground and, though they turn green and try to function as green leaves, they do not long remain and so are not serviceable to any extent as foliage leaves. The cotyledons of seeds like the squash (Fig. 169) and castor bean come above ground, turn green, and serve as the first foliage leaves of these seedlings. In the bean, pea (Fig. 151), and corn embryos the leaves of the plumule are the first foliage leaves.

II. Conditions That Are Essential for the Growth of Plants

188. What five conditions are essential for the growth of green plants. Light, air, moisture, and favorable temperature are essential to plant growth. We have shown in Exercise 18 that green plants can manufacture carbohydrates only in the presence of sunlight. We also showed in Exercise 23 that oxygen is necessary for the germination of seeds and for the release of energy in living as well as in lifeless things. It is possible also to show by experiments the relation of moisture and temperature to the sprouting of seeds and the growth of plants.

For the successful cultivation of individual plants or of crops one of the most important factors is the right kind of soil. This supplies to the plant the minerals necessary for living substance and determines to a very large extent the available supply of water.

189. What the character and the chemical composition of various kinds of soils are. Year by year the scientists in the Agricultural Bureaus at Washington and in the various states are learning more and more about the marvelous resources in our soils and are applying this knowledge in

helping the farmers to secure increased and more varied crops. The soil expert now comes to the intelligent farmer who has sought his advice, takes up samples from the soil the farmer is plowing, mixes them well, and finally carries away some of this mixture. In the laboratory he examines

Fig. 171. — Preparing soil for planting
Note that the plow turns under the top soil.

it under the microscope to see whether the particles are fine or coarse. He determines whether the soil can hold a large or a small amount of water. He tests it chemically to see whether it has the right proportion of the chemical compounds containing the four essential elements — nitrogen, potassium, phosphorus, and calcium — for when any one of these is wanting, the crops fail to grow (Fig. 13).

When the examination is finished, the expert can tell the farmer whether he can succeed better by growing in his soil wheat or potatoes, corn or onions. In many cases too, like the family physician in the home, the agricultural adviser can improve "sick" soil with nitrogen-fixing bacteria (**229**) or prescribe the needed fertilizers. Often astonishing results come from following his counsel.

REVIEW QUESTIONS

1. Locate and describe three structures seen on the concave edge of the bean seed. State the cause or the use of two of these structures.

2. Name three kinds of organs that comprise the bean embryo. Give the number and a description of each kind.

3. State the changes that take place in each of the organs you have just named, (*a*) in the bean seed that has just begun to sprout; (*b*) in the seedling just breaking through the ground; (*c*) in the fully developed seedling.

4. Of what two parts does a corn grain consist? Which part is alive? What is the use of the other part?

5. Name three or more parts or organs of which the corn embryo consists. State the changes that take place in each of these parts as the corn seedlings develop.

6. Name five conditions that are necessary for the growth of green plants.

7. In what way have we already shown that two of these conditions are essential for plant growth?

8. Name two ways in which soil contributes to the growth of plants.

9. Describe the method employed by a soil expert to determine the characteristics of soil. What advantages does a farmer derive from such an examination?

PART III

PLANTS AND ANIMALS IN RELATION TO HUMAN WELFARE

CHAPTER XVI

HOW MICROSCOPIC ORGANISMS ARE RELATED TO HEALTH AND DISEASE

I. Health and Disease

190. What is meant by health. We have already considered the various activities that must be carried on by all living organisms if they are to continue their individual existence and perpetuate their kind. When these nutritive and reproductive functions are performed by the organs, tissues, and cells of the plant or animal under favorable external and internal conditions, the organism is in a healthy condition. Too much emphasis can not be laid upon the importance of maintaining health, for thus only can man attain happiness for himself and others and do his part in the world's work. *The healthy organism is one in which all the cells are working together, or coöperating, for the common good.*

191. What is meant by disease. The cells of living things are often unable to carry on their own work effectively or to coöperate with other cells to the fullest extent. As a result the whole organism may fail to develop normally, or it may even cease to function. The failure of cells to function properly may be due to a variety of causes. In man and higher animals these abnormal conditions often give rise to sensations of discomfort or pain. The person is ill at ease — hence the term "disease" (from the Latin, meaning *lack of ease*). The term "disease" may refer either to such a mild disturbance as that caused by overeating or

to the very serious symptoms that often occur in cases of typhoid fever or pneumonia. (It is not necessary, however, that there should be evidence that the plant or animal is suffering pain or even feeling discomfort.) In its broadest application, therefore, the term "disease" may be used whenever the work of the cells of a plant or animal is being interfered with.

192. What have been some common ideas as to disease and its causes. The earliest records of human history show that man was a victim of diseases, probably the same as those which attack him now. Various beliefs were held as to the cause of these bodily ills. Many of the earlier races regarded disease as due either to evil spirits or to punishment by the gods; hence medical treatment was closely associated with religious rites and incantations. Among uncivilized peoples these ideas still prevail. Indeed, it is astonishing how ignorant and credulous the average individual even among the more enlightened peoples is in matters relating to the cause and treatment of sickness. For instance, various charms are worn to ward off disease, horse chestnuts are carried in the pocket to cure rheumatism, warts are believed to disappear as a result of magic, and certain herbs are supposed to owe their efficacy to the fact that they were gathered at definite phases of the moon. The enormous sale of patent medicines in our country has been largely due to the willingness of the average individual to believe in the claims of those who advertise the cures wrought by their nostrums.

193. What science has revealed respecting the causes of diseases. Medical science has proved that a large number of diseases which afflict humanity are due to various living organisms, most of them microscopic in size, which have found favorable conditions for growth in or on a larger organism. There these organisms give rise to conditions that are recognized as diseases of various kinds. Among diseases

thus caused are tuberculosis of man and of animals and the rusts and smuts that grow on wheat and corn (238).

194. How scientists discovered the relation of microscopic organisms to disease. In Chapter V we discussed briefly the use of the microscope in the discovery of the cells of which the higher plants and animals are composed. It was the Dutch investigator Leeuwenhoek, who also found that water in which dead plant or animal material was decaying contained countless microscopic plants and animals. Some of the living forms were changing shape like the amœba (see Chapter XXII), others were capable of rapid motion, and still others were tiny rod-shaped plant cells, now called *bacteria*.

As early as the eighteenth century it was suggested that such microörganisms might be the inciting causes of certain diseases. About 1873 the *germ theory of disease* was established. To Pasteur we are most indebted for the application of this knowledge to the prevention and cure of infectious diseases in plants, animals, and man (215).

But we must emphasize the fact that in reality only a relatively small number of kinds of microörganisms have any relation to disease. Indeed, the great majority are either harmless or distinctly beneficial. We are now to learn something of one great group of the microscopic plants already referred to as bacteria.

II. Structure, Growth, and Reproduction of Bacteria

195. What we know of the appearance and size of bacteria. Everyone knows that, when a bouquet of flowers is left for some time in a vase of water, the stems decay and give off disagreeable odors. This is a common example of the action of bacteria, for decay is the result of the work of these organisms. When we examine the stems or the putrid

water, we find a slimy scum. If we put a drop of this scum on a slide under a cover glass and examine it with the highest powers of the microscope, we usually see many different forms of living things. Some of them, the single-celled animals, appear relatively large. A closer examination will disclose countless numbers of very minute organisms; these are the bacteria.

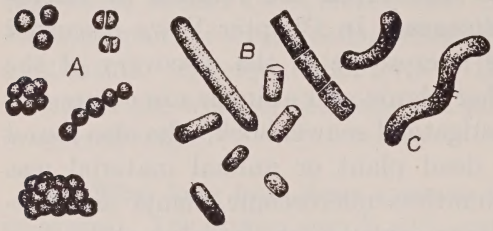


Fig. 172. — Various forms of bacteria

A, spherical (cocci); *B*, rod-shaped (bacilli); *C*, spiral (spirilla). Note the reproduction by cell division. (From Buchanan.)

A careful study of many kinds of bacteria shows that they have several characteristic shapes. Some are rod-shaped, some are spherical, some are egg-shaped, and still others are spiral in form. Each bacterium is a translucent bit of protoplasm with no definite nucleus. Because of their structure and method of nutrition biologists now regard them as plants rather than as animals (Fig. 172).

Some kinds of bacteria have one or more long hairlike

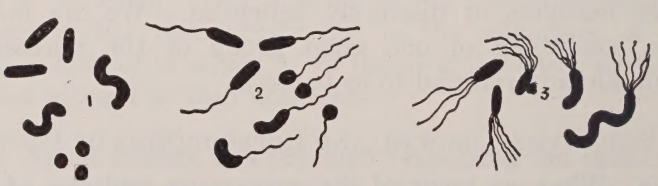


Fig. 173. — Bacteria without and with flagella

Flagella are hairlike projections for locomotion. 1, bacteria without flagella; 2, bacteria with a single flagellum; 3, bacteria with several flagella. (From Buchanan.)

projections from the ends which lash about rapidly and thus drive the individual through the water (Fig. 173).

Spiral bacteria roll over and over and advance in a spiral path.

It is very difficult to get a clear idea of the extreme minuteness of bacteria; indeed, bacteria vary in size from those that can be seen readily when enlarged 100 times to those that are so tiny that they scarcely can be distinguished when magnified 1000 times. The imagination may be somewhat assisted if we remember that 1500 rod-shaped bacteria, arranged end to end, would scarcely reach across the head of a pin.

EXERCISE 53

Microscopic study of bacteria. Laboratory demonstration.

Place on a glass slide a drop of the scum found on the surface of a hay infusion, and cover with a cover glass. Examine with the highest power of the compound microscope.

1. Describe the source of the material you are examining.
2. Which of the different forms of bacteria shown in Fig. 172 do you find? Draw several of the different shapes that you see.
3. Do any of the bacteria seem to be in motion? If so, describe the motion.
4. Add a drop of eosin or red ink to one side of the cover glass and then examine. State the result.

196. How bacteria reproduce. When conditions are favorable, the production of new bacteria goes on with marvelous rapidity. The process is somewhat as follows: The tiny cells take in through the cell wall some of the food materials that are about them, change this food into protoplasm, and increase somewhat in size. The limit is soon reached, however, and the bacterium begins to divide crosswise into halves, as does Pleurococcus. The mother cell thus forms two daughter cells asexually by making a cross partition between the two parts. If the daughter cells cling together, a chain, or a mass, is formed. Often they

separate entirely from each other. In either case the whole mass of bacteria is called a *colony*.

It usually takes about an hour for the division to take place. Suppose that we start at ten o'clock some morning with a single healthy bacterium. If conditions were favorable, there would be two cells at eleven o'clock; by twelve each of these two daughter cells would have formed into two granddaughter cells; the colony would then number four individuals. Should this process continue for twenty-four hours, the colony would number 16,777,216 bacteria. Such startling possibilities as those just suggested fortunately seldom become realities, for some of the favorable conditions soon cease to exist and the bacteria either die or cease to multiply.

197. How bacteria form spores. Sometimes, when food or moisture begins to fail, the protoplasm within each cell rolls itself into a ball and covers itself with a much thickened wall. This protects it until it again meets with conditions favorable for growth. This process is known as *spore formation;* the tiny *protoplasmic* sphere is called a *spore*, and its dense covering a *spore wall* (Fig. 174). In this condition bacteria may be blown about as a part of the dust. They may be heated even above the temperature of boiling water without being killed. When at length they settle down on a moist surface that will supply them with food, the spores

Fig. 174. — Spore-forming bacteria
Bacteria like these cause lockjaw.

burst their thick envelope, assume once more their rod-shaped or spiral form, and go on feeding, assimilating, and reproducing their kind.

198. How bacteria grow. Like other plants and animals bacteria must have food, moisture, some source of oxygen, and favorable temperature. These necessary conditions are secured in culture dishes prepared as follows: A Petri dish is first cleaned and then heated hot enough to kill any living organisms that may be in it. Then it is partly filled with a hot gelatinous solution which contains the food substances bacteria need.[1] On cooling, this food substance forms into a jellylike layer on the bottom of the dish. Thus we supply all the essential conditions for the culture of bacteria, and all that is necessary is to bring the germs in contact with the sticky surface. Bacteria may also be cultivated in sterilized test tubes partly filled with sterile beef tea, gelatin mixture, or potato, the tubes being then plugged with cotton.

EXERCISE 54

Where are bacteria found? Laboratory demonstration.

Treat the several Petri dishes in the following way and label each dish in accordance with its treatment. Keep one dish closed throughout the experiments and label it, "No. 1, Unopened Dish." Remove the cover from dish No. 2, and expose the surface of the agar for 10 minutes; replace the cover and label, "Exposed to Air of Schoolroom." In a distant part of the room stir up the dirt on the floor by using a broom, duster, or dry cloth, and then uncover dish No. 3, leaving it open to the dust for 10 minutes; replace the cover and label, "Exposed to Dusty Air." Allow the water to run from the faucet for several minutes, and then let a drop run over the surface of the agar in dish No. 4. Dilute a teaspoonful of milk with ten times its volume of distilled water or water that has been recently boiled and then allowed to cool; spread a drop of this mixture on the surface of the agar in dish No. 5. In dish No. 6 put a bit of raw meat, a bit of apple peel, and bits of other kinds of food.

[1] For preparation of food material for bacteria see Appendix II.

Touch the surface of one side of dish No. 7 with the finger tips. Lay a hair on the surface of dish No. 8. Scratch several times the surface of the agar in dish No. 9 with a toothpick that has been used in cleaning between the teeth. Make sure that each dish is properly labeled. Put all the dishes in a warm, dark place, and examine them at intervals of several days.

1. In what four respects are the conditions the same for all of the dishes?
2. State the difference in the treatment of the various culture dishes.
3. The spots on the surface of the agar are *colonies of bacteria*, each one of which may have developed from a single bacterium. Describe the appearance of some of the colonies, and if possible make a drawing of all the colonies that are found in one of the dishes. (If any of the colonies appear to be hairy or fuzzy, they are probably colonies of *molds*.)
4. What do you infer as to the presence of bacteria in air, water, milk, foods, and on the human body?

EXERCISE 55

How may bacteria be killed? Laboratory demonstration.

Heat a dissecting needle in a hot flame to kill all the germs upon it. After it has cooled, touch a colony of bacteria growing in one of the Petri dishes, and then transplant the bacteria thus obtained into dish No. 10 by carefully raising the cover and making several scratches in the agar (*e.g.* the date of the experiment or the number of the room). In a similar way prepare dish No. 11, and then pour over the cuts some iodine solution, or other antiseptic. Put the dishes in a warm, dark place.

1. Describe the preparation of each of the dishes.
2. What difference do you find in the appearance of the cuts made in the agar at the end of several days? How do you account for this difference?
3. What reason have you for thinking that bacteria in wounds will be killed if iodine solution is put on the cut?

III. Bacteria as the Foes of Man

199. What injurious effects bacteria produce. Most of the common bacteria are either harmless or distinctly

beneficial to man (**229-231**). Bacteria that cause decay and so increase the fertility of the soil become the enemies of man when they feed upon the food materials used in our households. Every housekeeper knows that milk soon spoils unless kept in a cold place and that meat and many other kinds of food quickly decay if they are not cooked or otherwise preserved.

Unfortunately, too, there are certain bacteria, or *germs*,[1] that find favorable conditions for growth in living tissues of our bodies and by their growth are the inciting causes of certain diseases, such as tuberculosis, diphtheria, and typhoid fever. Later we shall see that scientists are fast learning effective methods of *preventing* the ravages of these disease-producing bacteria, which we may well speak of as "man's invisible foes."

200. Some methods of food preservation. We saw in **198** that bacteria thrive whenever they can get plenty of food and moisture and whenever the temperature is favorable for growth. Common experience tells us that whenever any one of these necessary conditions is wanting, bacteria cease to carry on their functions. If, then, we wish to keep food from spoiling, we need only to bring about conditions unfavorable for the growth of microörganisms.

Meat, eggs, and other food materials will remain in a more or less fresh condition for a long time if they are put into cold storage. We find also that a high degree of heat will kill bacteria, and so meats that have been cooked and milk that has been Pasteurized or scalded will keep longer than when left uncooked. If meat, vegetables or fruits are heated to the boiling point in cans and sealed up at once, they may be preserved for a long time.

[1] Disease producing bacteria are commonly spoken of as *germs*, or *microbes*. These terms also include single-celled animals that cause disease. In general it is unnecessary and unwise to teach boys and girls much in regard to the symptoms and effects of disease. But since so much can be done to *prevent* these diseases that we have mentioned and others that afflict mankind, it is essential that the young should learn about some of these bacteria that are all too common.

Beef, ham, and fish are often smoked to preserve them, while pork and codfish are soaked in a strong solution of salt (*brine*) to keep them from the decaying action of bacteria. Another method of preserving food is by *dehydrating*, or taking away its water content. Dried beef, dried apples, hay, and seeds will keep indefinitely. Previous to the passage of the Pure Food Law by Congress in 1906, many unscrupulous dealers were accustomed to use borax, formaldehyde, and other chemicals to prevent their food supplies from spoiling.

201. Proper methods of sweeping and dusting. From our experiments in Exercise 54 we found that large numbers of bacteria are present in the air of rooms. These circulate where dust is raised by the movements of people or by sweeping. Since each of the colonies that we found on the Petri dishes usually starts from a single bacterium, it is easy to show the relative number of germs present in the air under varying conditions.

The number of bacteria that may be found in a schoolroom, church, theatre, or living room has been proved by a long series of experiments to be very considerable, for with the ordinary methods of cleaning these rooms very few of the germs are removed. When a room is swept, most of the light dust particles are raised from the floor and mingled with the air. After a short time the room is dusted, often with a feather duster. The bacteria that may have settled are whisked off again into the air.

Most of the germ-laden dust, however, can be removed from our homes if they are cleaned in a proper manner. In a room that has not been used for three or four hours practically all of the bacteria and fine dust particles have settled out of the air upon the horizontal surfaces. For dusting, a cloth should be used, and *never* a feather duster. "Dustless dusters" may be bought or may be prepared by soaking a piece of cheesecloth or flannel in a mixture of wax and turpentine. By the use of these cloths most of the particles of dust can be taken up and then can be removed from the cloths by washing them. If carpets, rugs, and draperies are then cleaned with a vacuum cleaner,

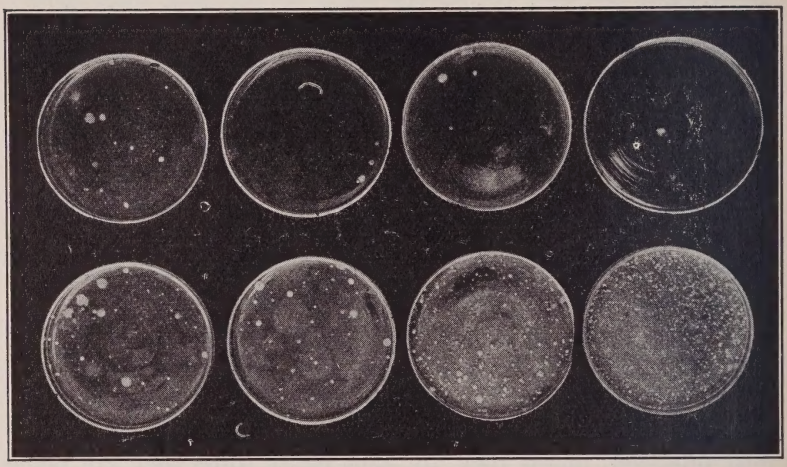
practically no dust is raised (Fig. 175); hence further dusting is unnecessary.

It is much more hygienic to have floors covered with rugs than with carpets, for, if a vacuum cleaner is not available, the dusty rugs and draperies can be removed from the room and cleaned in the open air. In general a carpet sweeper is to be preferred to a broom as a means of cleaning carpets, since fewer germs are stirred up than when a broom is used (Fig. 175). Whenever brooms are used, small moistened bits of newspaper or tea leaves should be scattered on the floor before the sweeping is done.

In the cleaning of public buildings the floors should first be sprinkled with moistened sawdust, and then the coarsest dirt should be swept up with bristle brooms. The floors should be washed frequently. Dirty streets too are a constant source of dust infection, unless they are kept moist while they are being swept.

202. Methods of treating open wounds. A vast amount of physical discomfort and possible danger from bacterial infection would be avoided if people would use proper care in the treatment of wounds. When one cuts a finger or gets a sliver into the tissues, the finger becomes swollen and sore, and white "matter," or *pus*, often forms in the vicinity of the wound. These effects are largely due to the activity of bacteria which have been carried into the wound. Finding in the tissues all the favorable conditions for growth, these minute organisms multiply rapidly and produce *toxins*, that cause the inflammation.

The body, however, has a very efficient means of protection. The blood in addition to red corpuscles has a relatively smaller number of *white corpuscles*. These have a very important function. As soon as the inflammatory processes that we have been describing begin in the wound, large numbers of white corpuscles from all over the body are hurried to the spot and begin to attack the invading bac-



A B C D

Photo by Elwin R. Sanborn

Fig. 175. — Bacteria colonies resulting from different methods of sweeping

Four rugs of the same size and approximately the same amount of use were selected, and placed at night in four different rooms. Early the next morning a Petri dish was uncovered in each room, and thus the nutrient agar of each dish was exposed to the air of the room for five minutes; after which the dishes were covered (upper row of dishes).

A second set of four dishes was then opened for five minutes while the four rugs were being cleaned as follows: rug D, with a dry broom; rug C, covered with pieces of wet newspaper and swept with a broom; rug B, with a carpet sweeper; and rug A, with a vacuum cleaner (lower row of dishes).

All eight dishes were closed and kept in a warm room for five days and then photographed. The number of bacteria colonies in each dish were counted, and the results are expressed in the following table:

	No. Colonies before Sweeping	No. Colonies after Sweeping	No. Times Colonies Were Increased by Sweeping
Dish D	4	1190	297 +
Dish C	6	436	72 +
Dish B	7	135	19 +
Dish A	25	118	4 +

teria. If the number of germs is relatively small and their virulence not excessive and if the corpuscles are in a healthy condition, these cells of the blood seize upon and devour the bacteria. Under these conditions little, if any, pus is formed. But if the bacteria get the upper hand in the struggle, many of the corpuscles are killed, and it is the dead white corpuscles that form the pus (Fig. 176).

A cut should be allowed to bleed freely to remove the bacteria that may have been brought in. The wound should then be covered with a sterile bandage. Wounds in which the bleeding is slight should be treated as soon as possible with iodine solution or other germ-destroying (*antiseptic*) solution. When iodine solution is used, it should be washed off with alcohol, in order to prevent the iodine from burning into the tissues. A bandage should then be applied to prevent the entrance of other germs. With proper treatment a wound should show no sign of inflammation or of the formation of pus and should heal rapidly.

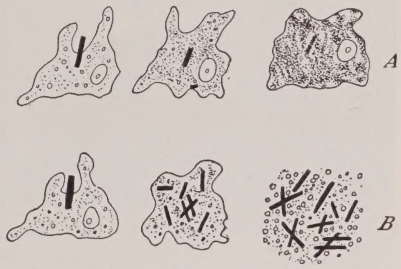


Fig. 176. — White corpuscles and bacteria

A, a white corpuscle devouring a bacterium; *B*, a white corpuscle destroyed by bacteria.

203. What causes tuberculosis. It is said that one seventh of all the deaths in the world are due to *tuberculosis*, more commonly known as *consumption*. In New York City alone the Board of Health reports 200 to 300 new cases each week. Yet, if the general public only knew the manner in which this disease is transmitted and would make use of this knowledge, the dreadful sacrifice of life and health due to this "great white plague" could be almost wholly prevented.

In 1882, Dr. Koch, a noted German scientist (Fig. 177), proved that tuberculosis is always caused by extremely small rod-shaped bacteria. He found countless numbers of these living germs in the sputum coughed up by consumptive patients. He cultivated these germs in test tubes; and when he injected the bacteria into the bodies of guinea pigs or rabbits, the animals became ill with tuberculosis (Fig 178).

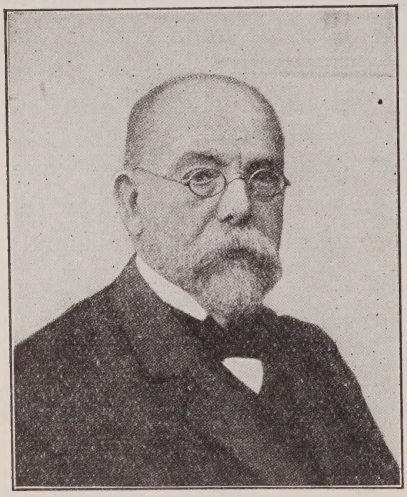
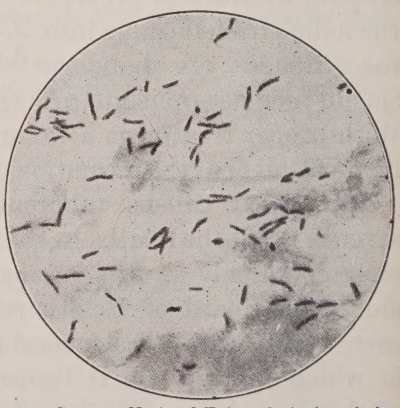


Fig. 177. — Dr. Robert Koch (1843-1910)

We are absolutely sure, therefore, that before anyone can become a consumptive, he must take into his body the living bacteria of tuberculosis, the common avenue of infection being through the nose and the air passages. When the bacteria get into the lungs of a person who happens to be a "little run down," as we say, straightway the bacteria begin to multiply, feeding meanwhile on the tissues of the lungs. If the malady is not arrested, the lungs may be gradually destroyed. For this reason



Courtesy National Tuberculosis Association

Fig. 178. — Bacteria of tuberculosis
Clouded areas are lung tissue. Photographed through the compound microscope.

the disease is called *consumption*. During the progress of the disease little masses, or *tubercles*, of lung tissue (hence the name *tuberculosis*) are thrown off by the patient in coughing, and these swarm with the living tuberculosis bacteria. Infants and young children are especially liable to infection if the germs can reach them. Hence milk that comes from cows which have tuberculosis is very dangerous to infants, but only slightly so to adults.

Courtesy National Tuberculosis Association

Fig. 179. — Home treatment of tuberculosis
Sleeping porch in the country.

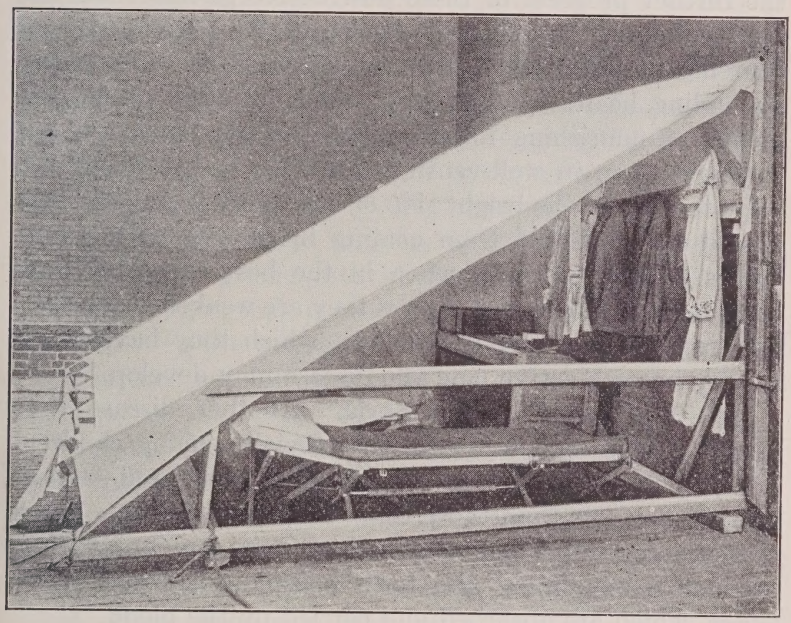
204. Some precautions that tuberculous patients should take. Consumptives through ignorance or carelessness frequently cough into the air a fine spray containing the living germs of tuberculosis, and anyone in the vicinity of the careless patient may inhale these virulent germs. It is of the utmost importance, therefore, that these living germs be kept out of the bodies of people who come in contact with consumptives. Responsibility in this matter rests very largely upon the patients themselves; and if they exercise the necessary care, they need not become a menace to healthy people in the home

or the community. It is of course essential that every effort be made to stop the filthy and dangerous habit of spitting. Many people have the disease long before they are aware of it, and a general public sentiment should be developed that will actively assist boards of health in enforcing their rules against the spitting nuisance. Every consumptive should expectorate in paper cups which should be burned.

Tuberculous patients should exercise great care not to cough or sneeze without covering the mouth or nose with the handkerchief, for it has been proved that living germs are widely distributed by carelessness in this regard. Indeed, this should be a general rule with everyone. Separate knives, forks, spoons, and drinking vessels should be set apart for consumptives, and these should be sterilized in boiling water after they have been used. Kissing on the lips, especially of children, should never be permitted, for this is a frequent cause of infection. The raw milk used by consumptives should be obtained from cattle that are certified as being free from tuberculosis.

205. Some methods of treating tuberculous patients. In former years the decision by doctors that a patient had tuberculosis was believed to be a sentence to a lingering death. It was believed, also, that this disease is hereditary. Happily modern medicine has dispelled both of these beliefs. A child may inherit weak lungs or a frail body; but he will never be a consumptive unless the bacteria that cause this disease are in some way planted in his tissues. Consumption is a curable disease, unless it is neglected until it has reached an advanced stage. The prime requisites in the treatment of the disease are a plentiful supply of fresh air, plenty of easily digested and nutritious food — such as eggs and milk — sleep, and freedom from muscular

work and from worry. A sufficient amount of outdoor air can be secured even in crowded cities by the use of tents on the roof (Fig. 180) or of window tents.



Courtesy National Tuberculosis Association

Fig. 180. — Home treatment of tuberculosis
Sleeping tent on the roof of a city apartment house.

206. What the individual can do to protect himself against tuberculosis. It must be evident from the foregoing discussion that the chances of exposure to the germs of tuberculosis are very great. Indeed, those who have examined the lungs of people who have died of other diseases maintain that a very large proportion give evidence of areas that have been attacked by tuberculosis germs. X-ray pictures frequently indicate the same in the case of healthy people.

We naturally ask why, in these cases, the disease did not progress sufficiently to become apparent. The answer is that the body cells were able to overcome and so to stop the further progress of these destructive germs. One can see, therefore, that vigorous health of the individual is of supreme importance in avoiding tuberculosis. To secure abounding health, young people and old alike should eat plenty of nourishing foods, exercise in the open air, get sufficient sleep in well-ventilated rooms, and endeavor always to look on the bright side of life. Very young children should be prevented from coming in contact with tuberculous people, for even when in the best of health they often become infected. Later, if they are weakened by other diseases, the germs of tuberculosis which they have taken in may become active, and the disease may develop.

207. The cause of diphtheria. Another disease that formerly claimed many victims, especially young children, is *diphtheria*. The germs of this disease are rod-shaped, somewhat larger than those that cause tuberculosis. When these bacteria find lodgment and grow in the throat, they produce a membrane and form poisonous substances, or *toxins*, which are absorbed and carried by the blood.

208. How diphtheria is treated. The cells of the body, however, at once set to work to produce substances that will neutralize or overcome the toxins formed by the diphtheria; these substances are known as *antitoxins*. When the disease is at its height, there is a fierce battle between the invading microbes with their toxins and the cells of the body fighting for their lives by means of the antitoxins. If the bacteria are victorious, death ensues.

In 1892 a most important discovery was made by a German bacteriologist, Von Behring. He found that it is not necessary for the human body to manufacture all the

antitoxin it needs for its struggle with the diphtheria poisons, but that this substance may be taken from the blood of other animals which have produced it. For this purpose healthy horses are now secured by city boards of health, and a small dose of *diphtheria toxin* is injected into their bodies. The next day a larger dose can be given with little or no effects. At the end of several months of this treatment, the animals can stand a quantity of the poison that would have proved fatal if given at an earlier time. For during all these days each horse has been having a mild form of diphtheria, and the cells of his body have been producing and giving into his blood an amount of antitoxin much more than is needed to neutralize the diphtheria poisons which the animal has been receiving. Some of the blood is then carefully removed and allowed to clot. The liquid *serum* that oozes out of the clot contains the antitoxin, which is prepared for injection into human beings when diphtheria attacks them. And so our good friend the horse, with no permanent ill effects to himself, has decreased the death rate formerly caused by diphtheria, until now it is less than one tenth what it used to be (Fig 181).

209. How diphtheria may be prevented. It is much more important to prevent attacks of this disease than it is to know how to cure it. So again we find strong arguments for the enforcement of rules against spitting, for living bacteria of diphtheria are often found in the throats of those who are thought to have ordinary sore throats. For this reason the mouth and the nose always should be covered when one coughs or sneezes. Children should be especially careful not to put into their mouths pencils, coins, or other objects that have been used by other children, for diphtheria germs have often been transmitted in this way.

In spite of all precautions that may be taken, on account

of crowded conditions among human beings or close contact, children are likely to be exposed to diphtheria germs that have been forced into the air by sneezing or coughing. Antitoxin may be administered to any members of the

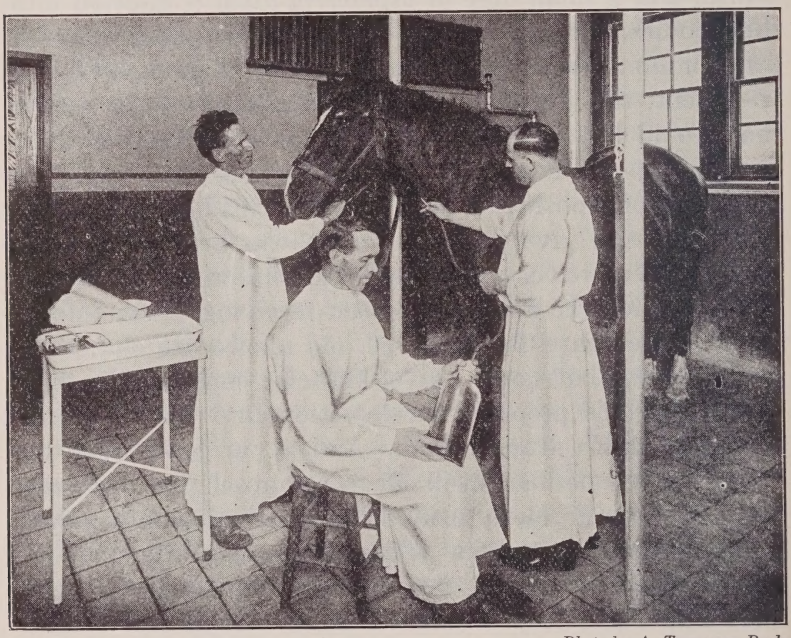


Photo by A. Tennyson Beals

Fig. 181. — Securing antitoxin from a horse

Since 1911 this horse has furnished over $100,000 worth of serum.

family who have been exposed to diphtheria; it then becomes a means of preventing the disease, but this protection is found to last but a few days only.

When a disease like diphtheria becomes epidemic, some people never take it since they have a natural immunity. In some diseases, such as smallpox, measles, and scarlet fever, one attack usually renders a person safe from a re-

currence. This is not true, however, of diphtheria. Fortunately, a method known as the *Schick test* has been discovered which enables a physician to determine whether or not a child is naturally immune. If it is found that he is not immune, a mixture of diphtheria toxin and antitoxin is injected, and thus the child is protected from infection for a number of years. More than 500,000 children living in New York City have received this protective, or *immunizing*, fluid within the past two years.

210. The cause of typhoid fever. This disease also is caused by the growth in the body of rod-shaped bacteria. These typhoid bacteria have hairlike projections which vibrate rapidly and so enable the germs to move about (Fig 182). The bacteria of typhoid fever are practically always taken into the body through the mouth and thence into the intestines. Food and drink are the vehicles which serve for the entrance of the bacillus; water and milk are probably the most frequent sources of infection. Milk is especially dangerous from the fact that typhoid bacteria not only live but multiply in it. Water and milk are dangerous, however, only when they actually contain the typhoid bacteria which have entered into them from the intestinal or kidney excretions of typhoid patients. It has been proved over and over again that the common house fly is frequently the means by which typhoid fever is transmitted. These

Courtesy Dr. W. H. Park

Fig. 182. — Typhoid bacteria
Observe the thread-like structures (flagella).

insects often alight on the excrement of typhoid patients and then carry the germs on their sticky feet, and so they infect the foods on which they alight (Fig. 261).

211. How typhoid fever may be prevented. If the excrement from the intestines and the kidney secretions of typhoid patients were thoroughly disinfected by carbolic acid or other germicides, the spread of typhoid fever would be very largely prevented. However, the bacteria of this disease may continue to live and to multiply in the gall bladder or kidneys or intestines of some people who have had typhoid fever, even years after recovery from the disease. These people are called *typhoid carriers*. Epidemics of typhoid fever have been traced to typhoid carriers. We can see, then, how important it is that boards of health make a careful inspection of those who handle foods.

One of the most difficult problems that formerly confronted armies was that of preventing typhoid infection. In the Mexican War and in the Civil War the armies on both sides paid frightful toll to this dread disease. Even in the Spanish-American War five thousand men in the United States army died of typhoid fever or other water- or fly-borne diseases, while only three hundred were killed by Spanish bullets. Since that time, however, sanitary camps with pure-water supply and means of preventing the breeding of flies have greatly improved conditions. In recent years an antityphoid vaccine consisting of dead typhoid germs is injected as a means of prevention. The results of the use of this vaccine have been most favorable. The general improvement in army health is strikingly shown by comparing figures for two army divisions of about the same size, one at Jacksonville, Florida, during the Spanish-American War in 1898 and the other at San Antonio, Texas, during the 1911 maneuvers on the Mexican border.

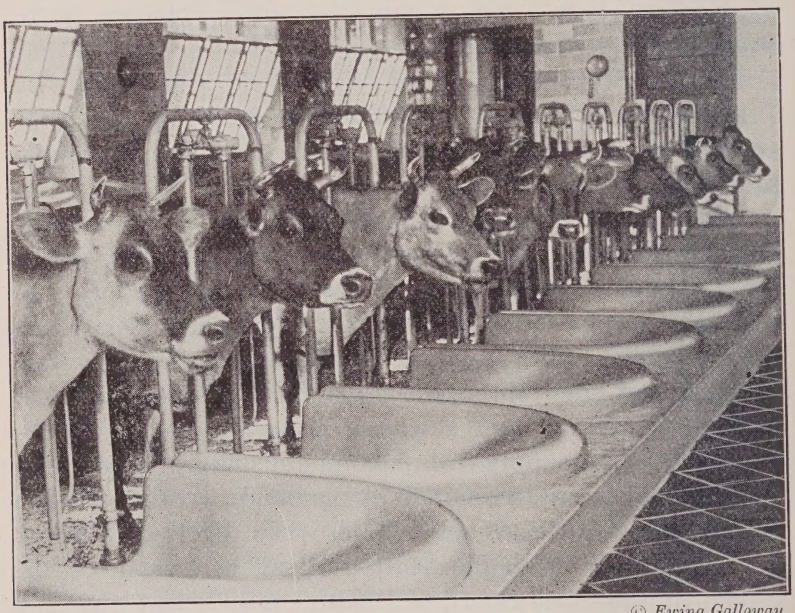
	Jacksonville 1898	San Antonio 1911
Number of soldiers	10,759	12,801
Number of cases of typhoid (certain and probable)	2,693	1
Number of deaths from typhoid fever . .	248	0
Number of deaths from all diseases . .	281	11

In the World War all our soldiers and sailors received the antityphoid treatment with the result that the disease was practically unknown.

212. How water supplies may be kept safe. In country districts each house usually has its own well, and so the family becomes accountable for its own water supply. In this case great care should be taken to place the well in such a position that none of the drainage from the house or barn can soak through the porous soil into the well. Those who live in large towns or cities almost always obtain their water supply from a common source. This sometimes becomes contaminated by typhoid or other disease germs, and a disease epidemic is then likely to follow. An emergency water-purification plant can then be installed by the State Board of Health. A sufficient quantity of chlorine is added to the water to destroy all dangerous foreign matter. If this can not be done, boards of health should notify the householders, and the water, when used for drinking purposes, should be boiled and then kept on ice until used.

213. How milk supplies may be safeguarded. Families in rural communities who keep cows can be sure of clean milk if they only take the necessary trouble. Cows need plenty of light, air, wholesome food, and clean surroundings (Fig. 183). If any of these is wanting, the animals are likely

to become diseased, and the milk is then affected. In sanitary dairies great care is taken at milking time to see that the surface of the body of the cow, especially about the flanks and udders, is brushed and then wiped with a



© *Ewing Galloway*

Fig. 183. — A sanitary cow stable

Provision for light, air, cleanliness, and the comfort of the cows has been made.

moist cloth and that the hands and clothing of those who do the milking are kept clean.

No one who has an infectious disease is allowed to have anything to do with the care of cows or of the milk. Over and over again epidemics of diphtheria, scarlet fever, typhoid, and of tuberculosis in infants have been traced along the routes of careless milkmen. At the present time public

Courtesy Metropolitan Life Insurance Co.

Fig. 184. — Careless handling of milk

Flies are carriers of disease germs.

Courtesy Metropolitan Life Insurance Co.

Fig. 185. — Careful handling of milk

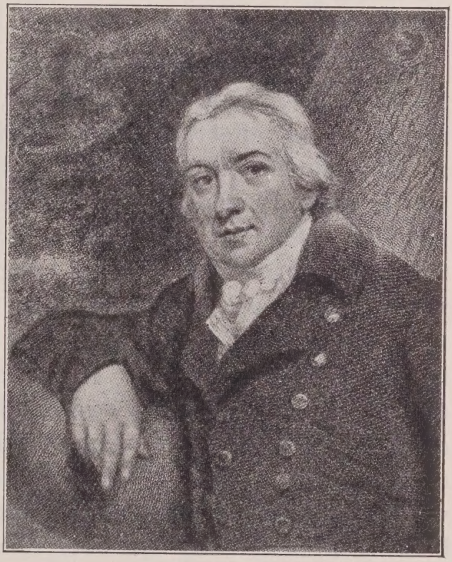
When bottled milk is used, it is safest always to wash the bottle thoroughly before using or placing in the refrigerator.

health authorities test cattle to see that they are free from tuberculosis. The diseased cattle are killed.

Those who live in cities are wholly dependent for milk upon sources they know nothing about. The milk that is consumed in New York City, for instance, comes from over 40,000 dairies, scattered through six different states. It is of course impossible to make any proper inspection in such a wide field. The New York Board of Health is doing all it can in this respect, and so far as possible it prevents dirty and dangerous milk from being sold. The only path of safety lies in the careful Pasteurization of milk and cream that are used for drinking purposes especially by young children. In communities where Pasteurization is insisted upon there has been a surprising decrease in the percentage of sickness and deaths from intestinal diseases, especially in the summer time and among young children. If the only milk obtainable is of a doubtful quality, it can be made safe by bringing it to the boiling point for a few minutes.

214. Smallpox and vaccination. — Smallpox was once so common that scarcely one person in a hundred escaped it. It was introduced into America by the Spaniards, it destroyed 3,500,000 people in Mexico and spread with frightful rapidity throughout the New World, until in 1733 it nearly depopulated Greenland. Mankind is indebted to Dr. Edward Jenner (Fig. 186), an English physician, who in 1796 proved that vaccination is a sure method of preventing the disease. In vaccination our bodies receive germs that originally came from smallpox, but which have been so modified that they cause a mild form of disease very different from smallpox itself. The cells produce some form of antitoxin which is effective protection when we are exposed to the disease. This kind of protection does not last indefinitely, however, and every person should make sure that successful vaccination is per-

formed at least once in ten years, and oftener than that if cases of smallpox develop in the community in which he is living. If a person has been actually exposed to the disease, he should be vaccinated immediately. Since the introduction of compulsory vaccination, smallpox is becoming very rare.



Courtesy Dodd, Mead & Co.

Fig. 186. — Dr. Edward Jenner (1749-1823)
His discovery has saved millions of people from an untimely death and still other millions from disfigurement.

215. Hydrophobia and the Pasteur treatment. — Hydrophobia, or *rabies*, is a disease due to the bite of a mad dog, cat, or wolf. Until the latter part of the nineteenth century the only known method of treating this disease was that of burning out, or cauterizing, the wounds with hot irons or nitric acid. After a long series of investigations, however, Louis Pasteur, a French scientist, made known to the world the so-called Pasteur treatment (1885). Pasteur found that the disease was located in the spinal cord and that, if pieces of the spinal cord of a rabbit which had died of hydrophobia are allowed to dry in the air, the germs gradually lost their virulence. He therefore began the treatment of patients who had been bitten by mad dogs by injecting beneath the skin an emulsion made from the spinal cords which had been dried for fourteen days. Each day for twenty-one days an injection was made from a cord that had been dried for a shorter time. Since hydrophobia usually does not develop in human beings for two

weeks to four months after the bite of a mad dog, the cells of the body by this Pasteur treatment gradually acquire the power to resist the hydrophobia toxins, and so the disease is prevented if the wound is cauterized at once and treatment begun immediately. The cauterization is of value even after a delay of twenty-four hours.

216. What safeguards the body has against disease. In the first place, the tough outer skin, so long as it is unbroken, forms a most effective barrier to the entrance of bacteria. At the mouth and nose openings there is danger. Each of the nostrils is guarded by hairs that collect many dirt particles. On the mucous membrane lining the nose and throat still other bacteria are caught. The cells which line the windpipe are furnished with cilia which lash upward (Fig. 124) and help expel the germs that may have gone past the outer lines of defense. If the bacteria enter the stomach and the intestines in a living condition, many of them are digested with the food. And should the invading microbes reach the interior of our lungs, our muscles, or our brain, we can still rely upon the antitoxins which the cells of a healthy human body are ever ready to produce. In such contagious diseases as smallpox or scarlet fever, these antitoxins remain for a considerable time in the blood to make us immune against a second attack. The white corpuscles are ever ready to pounce upon the bacteria, either to devour them or to carry them off from the body. An optimistic view of life and freedom from worry are undoubtedly very important factors in keeping the body in a state of vigorous health. A happy way of looking at life acts on the body somewhat like oil on the working of machinery. Oil prevents friction in a machine. Optimism enables the body to carry on the work more smoothly.[1]

[1] For a discussion of malaria and yellow fever see 274-276.

Common Diseases That Afflict Mankind — Their Causes, Prevention, and Treatment

Name of the Disease	Organism Causing the Disease	How Organism Is Transmitted	Region of Body Affected	Means of Prevention	Method of Treatment
Tuberculosis	Rod-shaped bacterium	Milk or meat of tubercular cow; sneezing, coughing, kissing	Lungs and other organs	Pasteurization of milk; anti-spitting campaigns; care not to take in tuberculosis germs from mouth or nose of a consumptive; keeping body in vigorous condition	Plenty of fresh air, nourishing food, and freedom from hard work and from worry
Diphtheria	Rod-shaped bacterium	Putting infected objects in mouth; sneezing	Throat; bacteria producing the toxins are carried through the body	Care not to take in diphtheria germs from throats of patients; injection of toxin-antitoxin	Injection of antitoxin
Typhoid fever	Rod-shaped bacterium	Taking into the body infected water, milk, or other food	Walls of intestines; toxins are carried through the body	Sanitary care of food, especially water and milk; destruction of house flies; injection of antityphoid vaccine; quarantine	
Smallpox	(Not yet discovered)	Probably by contact	Skin	Vaccination with a mild form of germs (cowpox germs)	
Hydrophobia	(Not yet discovered)	Bite of dog or other animal that has the disease	Brain and spinal cord	Muzzling of dogs	Injection of liquid containing germs made less virulent by drying

Summary

Health is the normal condition of living things, when all the cells work together, or coöperate, for the common good. *Disease* is a condition in which the work of the cells is interfered with through either internal or external causes. Diseases, formerly believed to be due to the work of evil spirits, are now known to be very largely the result of the growth within the body of microscopic cells (*disease germs*) of either plant or animal origin.

Bacteria are very minute spherical or rod-shaped or spiral organisms without a definite nucleus. They exist practically everywhere. Under favorable conditions of warmth, moisture, food, and oxygen, they multiply so rapidly that millions may be formed in a day. When conditions are unfavorable, many kinds of bacteria form thick-walled *spores*. Spores may be blown about in the air for some time or even subjected to a boiling temperature without being killed. Fortunately most bacteria that cause disease do not form spores. Bacteria are kept from growing or are killed by very cold or very hot temperatures, by dryness, by the use of preservatives (*e.g.* salt, spices, and vinegar), or by iodine, carbolic acid, or other antiseptic solutions.

Cuts should be allowed to bleed freely for a short time in order to wash out the bacteria and should then be covered with a sterile bandage. Iodine solution should be used in treating wounds where bleeding does not occur. The body is protected from disease germs by the skin (as long as it is unbroken); by the hairs of the nostrils; by the moist mucous lining of the nose, mouth, and throat; by the ciliated cells of the air passages; by the white corpuscles; and by natural immunity or by immunity secured by antitoxins or vaccination.

REVIEW QUESTIONS

1. What is meant by health? Give several reasons why vigorous health is important.

2. What is meant by disease? What kinds of living things are subject to disease? What are some of the indications of disease in man?

3. Give some account of superstitious ideas relative to the cause of diseases. Describe some former methods of treating diseases.

4. What is the modern scientific theory of the cause of most common diseases? To whom is the world most indebted for our knowledge of the cause of disease?

5. Give an account of the form, size, and structure of bacteria. Why are bacteria regarded as plant cells?

6. How are bacteria prepared for microscopic study? Describe the microscopic preparations you examined.

7. Give an account of the method of reproduction of bacteria and of the rate at which this occurs.

8. Describe spore formation by bacteria. Why is this process important?

9. Describe the preparation of Petri dishes for the growth of bacteria. What favorable conditions for cultivating bacteria are supplied in the Petri dishes?

10. Give an account of the experiments performed to show where bacteria may be found and how they may be killed. What is your conclusion from each experiment?

11. Name several ways in which germs are "man's invisible foes."

12. Why are cuts and other wounds likely to become a source of danger? Give directions for the treatment of wounds when the bleeding is profuse; when the bleeding is slight.

13. Give some idea of the prevalence of tuberculosis. Describe the work of Dr. Koch in connection with tuberculosis.

14. Enumerate some rules that should be followed by consumptives and give the reasons for each.

15. What ideas as to inheritance of tuberculosis were formerly held? What is probably the truth with reference to this matter?

16. What is the method of treatment of tuberculosis? What can the individual do to protect himself from this disease?

17. What kind of a germ causes diphtheria, and in what ways does this disease affect the body?

18. Define toxin, antitoxin, toxin-antitoxin, and serum, and show how each of these terms applies to diphtheria.

19. In what ways may diphtheria be prevented? Describe the use of the Schick test.

20. Discuss the cause of typhoid fever and possible ways of infection. Give an account of typhoid fever in connection with recent wars.

21. Tell how typhoid can be prevented by sanitary means; by anti-typhoid vaccination.

22. How are water and milk supplies rendered safe in country districts? In cities?

23. How can milk be rendered safe at its source? What precautions with reference to milk are taken by cities, and why is this necessary?

24. Name a disease that is prevented by (*a*) a vaccine composed of living germs weakened by cultivation in an animal; (*b*) a vaccine composed of living germs weakened by drying; (*c*) a vaccine composed of dead germs of the disease; (*d*) a serum containing toxin and antitoxin.

25. Name five or more ways in which the human body is protected against disease.

CHAPTER XVII

HOW PLANTS ARE RELATED TO HUMAN WELFARE

217. From what different points of view plants may be considered. Thus far we have considered the principal functions of plants and have observed some of their adaptations of structure for performing these functions. We have seen that, in order to live and grow, plants must manufacture, digest, and transport food and must breathe and carry on oxidation. In order to perpetuate their species, they must reproduce their kind. These are the *biological functions* of plants. But plants may be studied also from their *relation to human welfare.*

I. Uses of Plants for Foods, Beverages, or Medicines

218. Cereal foods. These foods include wheat (Fig. 18), corn (Fig. 187), oats, barley, rice, and others. All these belong to the *grass family,* which includes more species than any other botanical group. The stems and leaves of these plants and of other grasses, when dried as *hay,* form a great part of the winter supply of food for plant-eating (*herbivorous*) domestic animals. To man these cereal crops are most important because of the valuable *grains* (fruits with a single seed) that develop from flower clusters at the top or along the sides of the stems (Fig. 156). These grains furnish generous supplies of starch and to a less extent proteins, fats, and mineral matter. When they are dried and ground, they form flours or meals of various kinds, which, with the

possible exception of corn meal, may be kept indefinitely if kept dry.

These grain crops have been cultivated so long by man that scientists are not certain from what wild ancestor among

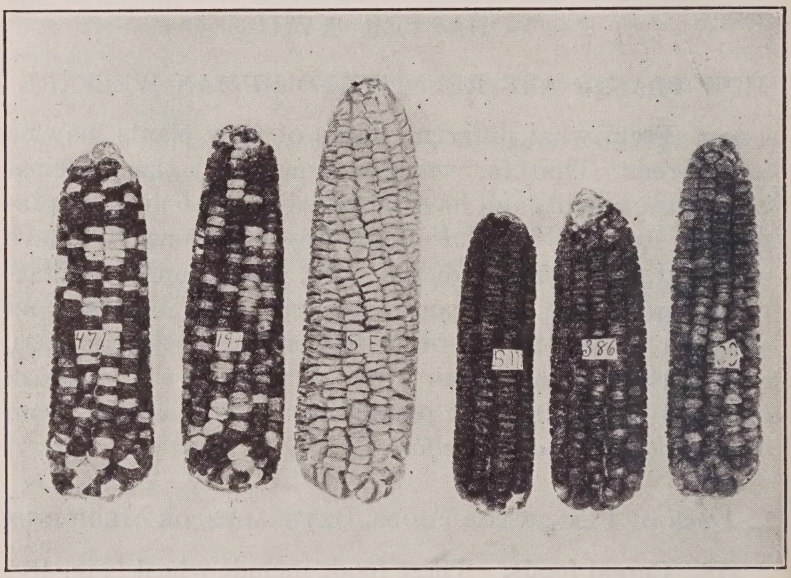


Fig. 187. — Cross-pollination of corn

The ears of pure white corn and pure black corn (Evergreen and Black Mexican) are the parents of the ears with mixed white and black kernels.

the grasses any one of them has sprung. Wheat, for example, has been found in the pyramids of Egypt; it must have been put there more than 3000 years before Christ. Many scientists believe that it was first grown by man in western Asia in the region of Mesopotamia. Barley and rice are of ancient origin; but oats and rye seem to have been domesticated somewhat more recently.

All the grains we have just mentioned were introduced into America by the early settlers. Corn, however, is truly

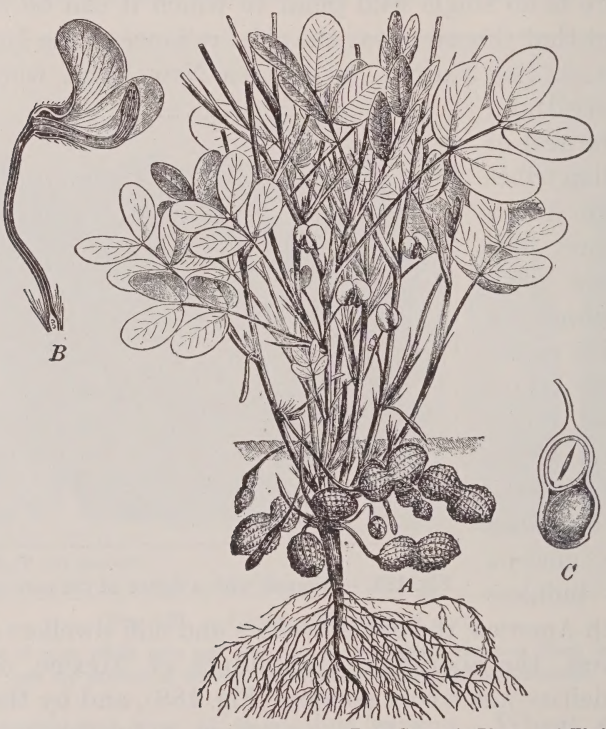
an American product, which was widely cultivated by the Indians both north and south of the equator, before Europeans came to this coast. Its origin also is a mystery, for there is no single wild plant to which it can be traced. The fact that this crop was the chief reliance of the Iroquois Indians, or Six Nations, of western New York, who were more civilized than the rest of the Indian tribes of North America, shows how important cultivated crops are in helping to develop the beginnings of civilization. Corn was also extensively cultivated by the ancient mound builders of North America, the cave dwellers and cliff dwellers of the Southwest, the aboriginal inhabitants of Mexico, one of whose deities was a corn goddess (Fig. 188), and by the subjects of the Incas of Peru, to whom it furnished a food and a fermented drink and in whose graves it is found in great abundance.

Courtesy Dr. W. E. Safford

Fig. 188. — Utensil with a figure of the corn goddess

219. Pod-bearing plants. Beans (Fig. 53), peas (Fig. 151), and their relatives are likewise especially important sources of food to man because they contain more protein, or nitrogenous food, than any other group. Hence they are a fair substitute in our diet for the more expensive meats. When the crops of clover and of alfalfa (both of which are

pod-bearing plants) are cut, the stems and leaves supply needed food for cattle, horses, and sheep. The seeds of the bean and pea plants yield a considerable amount of



From Sargent's Plants and Their Uses

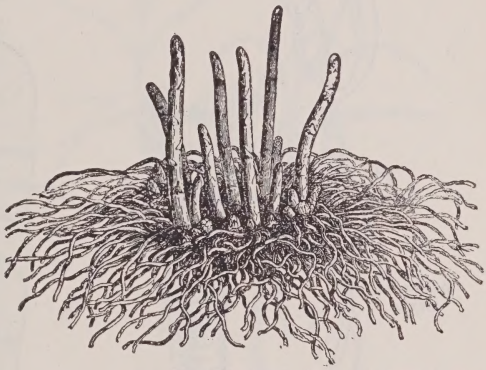
Fig. 189. — Peanut plant

***A*, a complete plant with flowers and fruits; *B*, a single flower; *C*, a two-seeded fruit, one seed cut in halves to show the two cotyledons.**

protein for man. Another important plant belonging to this group is the peanut. Its so-called nuts are really pods, which are developed, not in the air like beans and peas but in the ground, from peculiar flowers which penetrate the soil (Fig. 189). The roots of the pod-bearing plants

harbor a kind of bacteria that stimulate the growth on the roots of tiny enlargements known as *tubercles*. The bacteria in these tubercles are very important because they are able to make nitrates (**229**).

220. Other vegetable foods that form an important part of our diet are the leaves of cabbage heads, lettuce, and spinach; the leafstalks of celery and rhubarb; the stems of asparagus (Fig. 190) and the flower heads of cauliflower and artichokes; roots of beets, carrots (Fig. 191), parsnips, turnips, and sweet potatoes (Fig. 56); and the tubers, or swollen underground stems, of the white potato (Fig. 57). In all these the plants, under cultivation, have manufactured and stored away important food substances particularly in the form of mineral matter and vitamins. These coarser vegetable foods are also important in our diet since they form the "roughage" which tends to prevent constipation by stimulating the contraction of the intestinal muscles.



From Sargent's Plants and Their Uses

Fig. 190. — Asparagus plant

Note the great number of feeding roots and the numerous edible stalks.

The white potato originated in western South America. It is often confused by early writers with the sweet potato from which it is very distinct. Like corn, beans, squashes, and pumpkins, both the sweet and the white potato are products of the New World which we have received as an inheritance from the Indians. The white potato gets

its name "Irish potato" from the fact that at an early date it became an important food staple in Ireland, where it found favorable conditions of soil and climate.

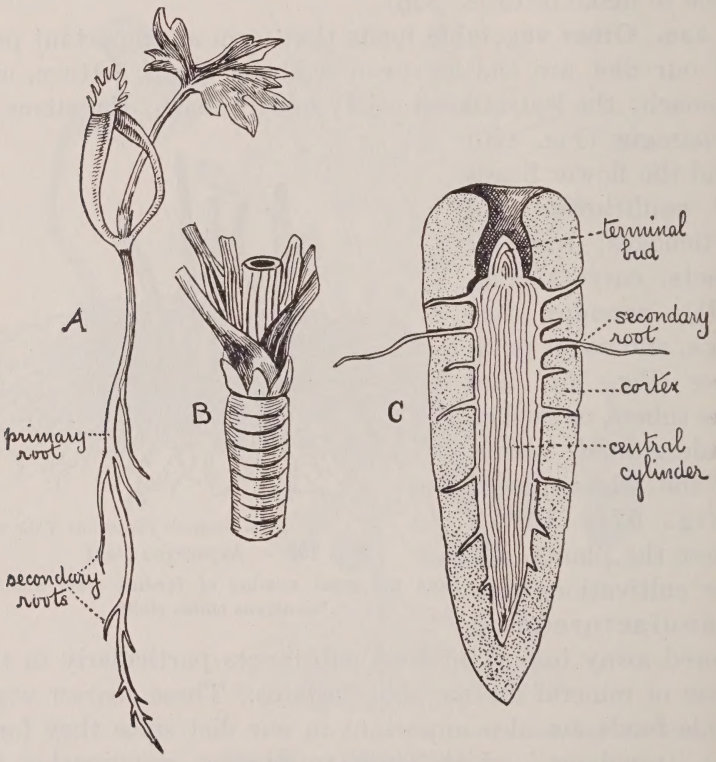


Fig. 191. — Carrot

A, young seedling; B, developing root; C, section of swollen root.

221. Beets and sugar cane are our principal sources of sugar. The general appearance of sugar cane (Fig. 192) shows that, like corn, it belongs to the grass family. Its stalks, after they are cut, are crushed between heavy rollers, and the sweet sap which gushes forth is boiled until

it thickens into sugar. From the crude brown sugar thus obtained, pure white sugar is produced by purification and crystallization. Beets as a source of sugar are especially important since, unlike sugar cane, they can be grown in temperate regions. When first cultivated these roots yielded only 3 to 4 per cent of sugar. By careful breeding and selection, however, this percentage of sugar has been multiplied four or five times. Both sugar cane and beets are Old World plants. In ancient America the principal sources of sugar were the sugar maple in the North (Fig. 193) and certain of the century plants in the desert regions of the southwestern part of what is now the United States and in Mexico. In tropical regions sugar was also obtained by boiling the sap of certain palms.

From Sargent's Plants and Their Uses

Fig. 192. — Sugar cane

222. Cultivated fruits. The list of these fruits available for the use of man is a long one. It includes apples, pears, plums, cherries, peaches, apricots, grapes, oranges, lemons,

Fig. 193. — Sugar maples

Observe the spouts driven into the tree trunks and the pails that catch the sweet sap.

mangoes, figs (Fig. 194), dates, bananas, pineapples, melons, and various kinds of berries, such as blueberries (Fig. 164), strawberries, raspberries, and blackberries. All these, when ripe, have a juicy pulp which we eat, the seeds usually being discarded. Other fruits are tomatoes (Fig. 195), egg plants, pumpkins, and squashes, which are prepared for the table like vegetables, and the avocado, or alligator pear, which is becoming more and more important in our fruit markets.

From Sargent's Plants and Their Uses

Fig. 194. — Fig leaf and fruit

Much could be written of the methods used by man to develop new varieties of fruits or to improve the flavor or the food value of old varieties (184). Our Concord, Delaware, Catawba, Niagara, and other varieties of grapes (Fig. 196) have been developed from wild American species. The delicious varieties of grape fruits are derived from inferior forms of Citrus by cross-breeding and through selection. Fruits and vegetables new to us are introduced yearly by the Federal Office of Foreign Seed and Plant Introduction, being obtained by agricultural explorers in many distant lands.

Many fruits are especially valuable on account of the acids they contain as well as for their mineral content and vitamins, which are important in the prevention and cure of scurvy (58). Among the cultivated nuts are almonds,

which are the seeds of fruits related to the peach and apricot; Persian walnuts, usually called "English walnuts"; European filberts; and American pecans. In the tropics the principal nut is the coconut, which yields food and a valuable oil (Fig. 198). The oily, nutritious seeds of certain pines, called piñones, are an important source of food in certain parts of the Old World as well as in America; and species of chestnuts are made into bread and prepared in various ways for food both in Europe and in Asia.

From Gager's Fundamentals of Botany

Fig. 195. — Grafting

A tomato grafted on a potato. Note the tomato on the stem and the potato on the soil surface.

223. Plants as sources of beverages. Coffee is derived from the seeds of small scarlet berries of a tree (Fig. 63), or shrub, which grows wild in Abyssinia in Africa. This tree is now widely cultivated in Java and other parts of the East Indies, in Central America, Brazil, and other tropical countries. Tea is an infusion of the leaves of a plant (Fig. 61) allied to the beautiful camellias of our hothouses. It has been cultivated by the Chinese from time immemorial and is now widely grown in Japan, Ceylon, and other tropical and subtropical countries. Its culture was undertaken in South Carolina with very successful results as far as the plant itself was concerned. But owing to the price of labor the tea produced in that state could not compete with imported teas, and the project was given up. *Thein*, the alkaloid to which tea owes its stimulating effects.

has been found by chemists to be identical with caffein, the active stimulant in coffee. From the seeds of the fruit of the cacao, a tree of the tropical forests of Mexico and Central America (Fig. 62), we obtain cocoa and chocolate which may be regarded as foods as well as stimulants.

Photo by Laval and Ninnis

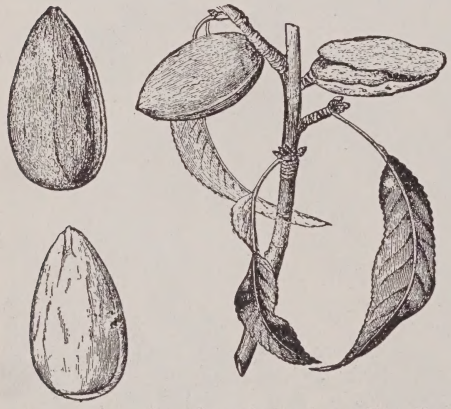
Fig. 195. — Raisin grapes grown in California

Many kinds of grapes are grown, some with seeds, others without. Seeds are removed from grapes by special machinery.

224. Plants as sources of flavoring extracts. The following products are used for flavoring our foods and beverages: *vanilla*, derived from the fermented fruit of a climbing orchid of the tropical forests of eastern Mexico; *pepper*, from the dried berries of the pepper vine (Fig. 60); *red pepper*, from the fruits of Capsicum; *cinnamon*, the pulverized bark of a tree belonging to the laurel family; *ginger*, prepared from the underground stalks of the ginger plant; *turmeric* (used for making curry powder) from an allied plant; *cloves*, the dried unopened flowers of a tree belonging to the

myrtle family of the Old World (Fig. 199); *allspice*, from the dried berries of an allied tree of tropical America; *mustard*, from the seeds of a plant related to the cabbage and turnip; *horse radish*, from the pungent root of another plant of the same family; many garden herbs, such as *thyme*, *sage*, and *mints* of various kinds; and aromatic seeds, like *anise*, *caraway*, and *celery*.

225. Plants as sources of drugs. *Quinine*, the well-known remedy for malaria, is obtained from the bitter bark of a tree known to botanists as Cinchona, which grows in the forests of Peru. This medicine is now obtained almost exclusively from trees that have been successfully introduced into Java. The camphor tree furnishes *camphor gum*. From the aromatic substances found in certain Eucalyptus trees *listerine* and other medicines are obtained. The fragrant leaves of *wintergreen* yield a volatile oil much used for flavoring foods and for medicines. The fruits of certain poppies (Fig. 64) yield *opium* and *morphine*. From Old World plants related to the tobacco are obtained *atropine* and *belladonna*, which are used as narcotics; from the hemp plant is prepared another narcotic, the *hashish* of India. The leaves of the Peruvian coca, which have been used from prehistoric times by the Indians of that country as a stimulant, supply *cocaine*, a most valuable drug which enables severe surgical operations



From Sargent's Plants and Their Uses

Fig. 197. — Almond twig and fruit

to be performed without pain. Other important narcotic plants are the various species of Nicotiana, which yield *tobacco* (Fig. 65) for smoking, chewing, and snuff.

II. Uses of Plants for Clothing

226. Cotton. Second only to the use made of plants for food by man is the importance of plants in furnishing materials for clothing. In order to be valuable in this way plants must develop tough *fibers* of some sort that can be spun into threads and woven into fabrics. Cotton is so valuable in this particular that before the Civil War the statement "Cotton is King" was common in the South. The cotton fiber is the most important fiber of the world. Cotton plants (Fig. 201) come from seeds, which in our country are planted each year, and ordinarily grow to a height of two to four feet. The fruits of these plants consist of cotton bolls (Fig. 202), each of which when ripe

Fig. 198. — Coconut palms
Note the pile of coconuts that have been gathered.

bursts open and thus liberates twenty to fifty seeds covered with long fibers. These fibers are spirally twisted and can be readily spun into threads.

The invention of the cotton gin by Eli Whitney in 1792 revolutionized the cotton industry, since formerly the separation of the cotton from the seeds had to be done by hand. From the seeds cottonseed oil is obtained. This oil is used in cooking, soap making, and as an adulterant of other oils.

Fig. 199. — Clove
B, section of flower bud; *F*, outside of flower bud.

There is no region of the world better fitted for cotton growing than is the Cotton Belt of our southern United States. From this region comes at present about 60 per cent of all the cotton produced in the world. In recent years, however, this most valuable product has been seriously menaced by the *cotton-boll weevil* (Fig. 202), a long-nosed beetle which crossed the Mexican border in 1892. This pest has steadily advanced until it has spread over most of the Cotton Belt and it is causing great damage each year. Thus far no way has been found to eliminate the insect, but its ravages are checked by the use of poisons. This loss bears heavily upon all of us, for it means a smaller crop and, therefore, higher prices for clothing.

Cotton was unknown in ancient Egypt. Fibers of several species of cotton, quite distinct from those of the Old World, were spun and woven by the inhabitants of the

warmer parts of America before the arrival of Columbus. Bolls of cotton were presented to him by the natives of the first islands he visited, and cotton fabrics woven by them won his admiration. In prehistoric graves on the coast of Peru looms, spindles, and cotton, both spun and unspun, have been discovered, and beautiful fabrics of cotton used for enveloping the mummies have been unearthed.

Fig. 200. — Typical plant of upland long-staple cotton

227. Flax. From this most useful plant linen fabrics are produced. The fibers used for this purpose form a part of the stem. After the pods are ripened, the plants are pulled, and the seeds removed.[1] The stems are then soaked in water for a time. By the growth of bacteria (195) the valuable fibers are *retted* (that is, rotted or softened) so that they can be separated from the rest of the stem. They can then be spun and woven into linen. Flax has been grown so long and so widely that we do not even know the country where it was first cultivated. "Fine

[1] From the seeds of this plant is obtained the linseed oil used in mixing paints. After the seeds are ground and the oil has been removed, the residue is found to be excellent food for domestic animals.

linen" is frequently mentioned in the *Bible;* the Egyptian mummies were wrapped in linen; and flax has been found in ancient Chaldean tombs.

228. Other fiber plants. *Hemp* and *jute* furnish very tough material used in making ropes. The coconut palm (Fig. 198)

Photo by Raymond, Dallas, Texas

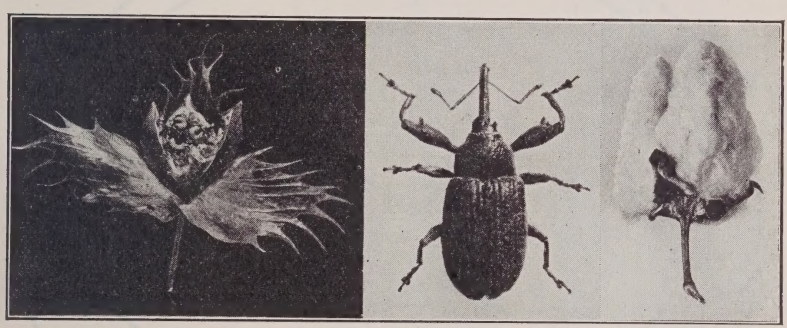
Fig. 201. — Picking cotton

supplies fibrous materials for the manufacture of mats. Straw hats and Panama hats are woven from the stems of various plants allied to the palms and the grasses. Century plants yield excellent fiber, and cordage of fine quality is made from the Philippine abaca.

III. Bacteria as the Friends of Man

229. In what ways bacteria are related to soil fertility. *The action of bacteria in causing decay.* Were it not for the never-

ending activity of bacteria, all life upon the earth would soon cease to exist. Why is this true? When animals or plants die, their bodies fall upon the ground; and were not these lifeless masses taken care of, the whole surface of the earth would be covered with a vast number of unburied organisms. All this dead material, as we have seen, is food for countless bacteria. They cause it to decay and thus decompose it into simpler chemical compounds that soak into



Courtesy U. S. Department of Agriculture

Fig. 202. — Cotton-boll weevil
At left, cotton boll destroyed by larvæ of boll weevil (center); at right, fully developed cotton boll.

the earth and serve as nutriment for the higher plants. Since plants are constantly taking from the earth the materials that they need to make food substances, this soil would tend to become less and less fertile, were it not for the work of the bacteria that cause decomposition. This is one reason why rotting manure adds to the fertility of the soil.

The action of nitrogen-fixing bacteria. It has been proved that certain kinds of bacteria directly increase the amount of nitrogen compounds that are so essential in the soil for plant growth. Corn and other crops will grow better in soil that has previously borne a crop of beans, peas, clover, or other members of the pod-bearing family. Within recent

years an explanation of this fact has been found. When the roots of these pod-bearing plants are examined, small swellings, or *tubercles*, are seen (Fig. 204). These tubercles contain multitudes of bacteria that are able to take the free nitrogen from the air between the particles of the soil

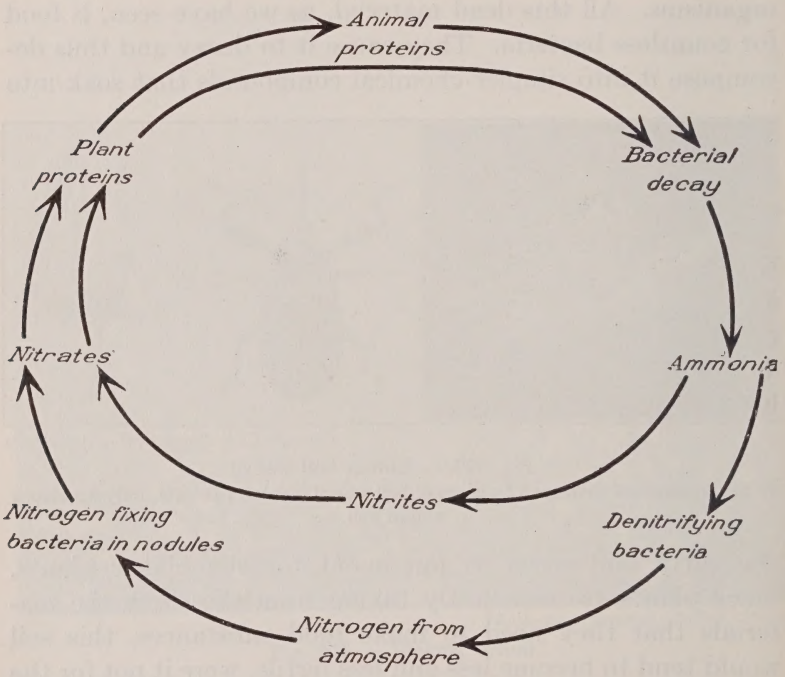
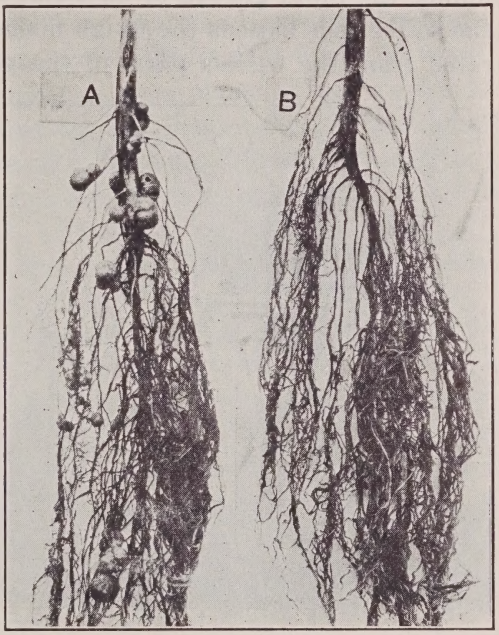


Fig. 203. — Nitrogen cycle
Compare with carbon cycle (Fig. 130).

and to combine it with sodium or potassium and oxygen, thus forming nitrates, which are very important minerals needed by all crops. Since these *nitrogen-fixing bacteria* can be supplied to soils that do not have them, it is possible to restore in this way much of the fertility that may have been lost (Fig. 205).

230. How bacteria are related to the flavors of food. Many flavors of food are due to the action of bacteria. The flesh of cattle that have just been killed is often tough and tasteless. If allowed to stand, however, these meats become tender and acquire their distinctive flavors by the decomposing action of bacteria.

A similar action takes place when *butter* or *cheese* ripens, and the dairy industry has been perfected to such a degree that bacteria of certain kinds have been proved to give rise to definite flavors. These bacteria can be produced in pure cultures for the dairyman by growing them on food substances in test tubes. They can then be transplanted into the milk.



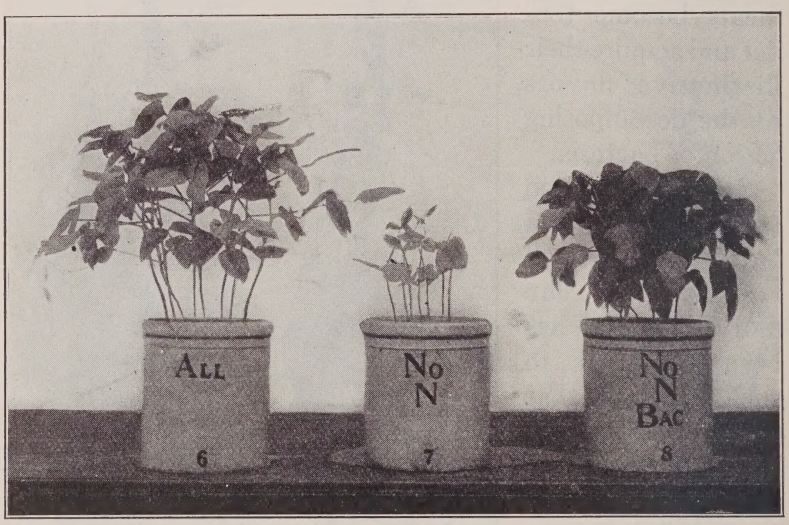
From Gager's Fundamentals of Botany

Fig. 204. — Action of nitrogen-fixing bacteria

A, roots of a soy-bean plant grown from a seed that was soaked overnight in a culture of nitrogen-fixing bacteria; B, roots of a soy-bean plant which was not supplied with the nitrogen-fixing bacteria.

231. How bacteria are related to the industries. Without the help of bacteria the preparation of the fibers of flax (linen), jute, and hemp would be impossible. These *plant fibers* are connected with the woody materials of the plants so closely

that they can not be separated unless the stems of flax, hemp, and jute are first subjected to a process of decay in large tanks or in streams of water. Moisture and warmth induce the rapid growth of bacteria; the resulting decay of the softer cells loosens the tough fibers so they can be separated from the useless parts of the plant. The change of



Courtesy College of Agriculture, University of Illinois

Fig. 205. — Relation of nitrogen to soil fertility

On the left, a complete fertilizer was used, but no soil bacteria were present; on the right, soil bacteria supplied the nitrogen; in center, plants had no nitrogen and no soil bacteria.

alcohol to vinegar is also caused by bacteria. Millions of bacteria known as "mother of vinegar" are found in the jellylike mass at the bottom of a vinegar bottle or barrel.

IV. The Uses of Forests and Forest Conservation

232. Uses of forests for fuel, lumber, and other commercial purposes. In the earlier days of our country's history all the fuel for heating and for running locomotives

and other engines was supplied from the forests. About one hundred years ago coal began to be used as fuel in Pennsylvania, and one would suppose that since that time our forests would have been drawn upon less heavily for fuel. It is estimated, however, that the United States burns annually at the present time 100,000,000 cords of wood. While we are considering the uses of plants as fuel, we should remember that our enormous coal beds were without doubt formed from great tree ferns (Fig. 36) and other plants that lived in bygone ages. Petroleum too, from which kerosene is produced, is a product of plant or animal decomposition; and so also is natural gas. Artificial gas is made from coal and oil and so is indirectly derived from plants.

One has but to call to mind the enormous use of trees for building purposes, for furniture, for railroad ties, for telephone and telegraph poles, for shipbuilding, for boxes, for barrels, and for paper manufacture to realize how indispensable are our forests. *Wood* is used for the manufacture of artificial silk, of which about 20,000,000 pounds is made in the United States in a year — nearly half the quantity of raw silk produced. Artificial silk or "silk fiber" is made from the cellulose extracted from various kinds of light-colored, nonresinous woods, such as spruce, aspen, basswood, and cottonwood. This industry has grown enormously in the last few years, largely because of the great increase in the production of silk hosiery and knitted sweaters and scarfs. Artificial silk is similar to real silk in appearance but is less expensive.

233. The value of forests in regulating the flow of streams and preventing erosion. We turn now from a consideration of our forests as a source of fuel, lumber, and raw material for manufactured products to a discussion of their effects on the flow of streams. It is the general belief among foresters

and nearly all other persons who are familiar with the conditions in mountainous regions that forests are of great value in protecting the surface of the soil from erosion

Courtesy U. S. Forest Service

Fig. 206. — Erosion due to removing all trees

(Fig. 206) and in regulating the flow of streams. Let us see on what these beliefs are founded.

When the rain falls upon the tree tops, the water drips from leaf to leaf and finally reaches the ground. Here it trickles down through the floor of the forest (Fig. 207), which is formed of thick layers of decaying leaves, interlacing roots, and earth particles. All these form a porous mass which absorbs and holds back the water like an enor-

mous sponge. The water thus retarded in its flow has time to penetrate the earth, and hence it finally reaches the water courses of the region without carrying away great masses of the soil. The time required for the run-off is increased,

Courtesy U. S. Forest Service

Fig. 207. — Floor of the forest

owing to the fact that the waters are spread out over a greater surface, instead of running down in gullies. The more rapidly the water runs, the greater its cutting and transporting power.[1]

[1] The erosive or cutting power of a stream varies as the square of the velocity. Thus if the velocity of a stream were increased from two to ten miles an hour, its cutting power would be multiplied twenty-five times instead of five times as one might expect. The transporting power of water varies as the sixth power of its velocity. So if the velocity of a stream is increased 10 times, its transporting power is increased 1,000,000 times. A current of two miles per hour will move fragments of stone the size of a hen's egg, weighing about three ounces; while a torrent of twenty miles per hour will carry boulders weighing nearly one hundred tons. — *Forest Service Bulletin, No. 91*, p. 14.

Suppose now that the trees are removed from the mountain sides. After a time the forest floor disintegrates; now, when the rains come, there is no effective way of absorbing the water. Instead it flows rapidly over the surface of the land from which the trees have been cut, carrying away the richest of the soil and cutting deep gullies in the hillsides (Fig. 206). The material thus carried away fills up the river beds and harbor mouths, and in many cases a heavy expense is entailed in its removal. If the rain is long continued, the streams are swollen into torrents which may bring destruction and death as they flood the valleys along their courses.

While the forest floor may do much in holding back the water, it has of course, like a sponge, a limit to the amount of water it can absorb. When this limit has been reached, if the rains continue, the water will run off on the surface and flood the streams in spite of the forests. The Forest Service of the United States Department of Agriculture began a very complete study of the effects of the forest cover on stream flow and erosion in 1910. The site selected for this experiment is near Wagon Wheel Gap, Colorado, in the Rio Grande National Forest. When this work is completed at the end of twenty years, we may have experimental proof to support our present belief that forests reduce the magnitude of floods, tend to maintain stream flow in dry weather, and reduce or prevent the washing away of fertile soil.

234. Dangers that threaten our forests. When the early settlers reached this country, they found vast areas of virgin forest. Their first work was to clear land in order to get open spaces for cultivation and for protection from attacks of the Indians. They cut down the trees ruthlessly, and the timber and wood which was not needed was left

to decay or become the prey of forest fires. Such forest destruction has continued even to our own day. Now men are beginning to see that, unless this slaughter of our trees is stopped, our timber supply will soon be gone. In fact, Government experts tell us that, if the forest areas that yet remain are not protected from fire and kept productive, we will soon suffer a timber famine. We are using up our timber four times as fast as it is being replaced by young growth. The original forests of the United States covered 822,000,000 acres; *they have now shrunk to one sixth of that area!* It is estimated that 81,000,000 acres of former forest land have been so severely cut and burned as to become an unproductive waste, which is equivalent to the combined forests of Germany (of 1914), Holland, Belgium, France, Switzerland, Spain, and Portugal.

The threatened destruction of our American forests by careless methods of lumbering means not only the wholesale cutting of large areas without leaving seed trees to provide for future forests, but also it means the leaving of these acres strewn with dry branches and tops to become the prey of destructive forest fires (Fig. 208). The annual loss of property from this cause is conservatively estimated at more than fifteen million dollars. The dead tree trunks and branches also furnish breeding places for insects, which prey upon healthy trees. Another destructive agency, especially to young forest growth, is the large flocks of grazing animals like cattle and sheep which feed upon and trample down the small trees. If we are to preserve the remnants of our once vast forest resources, a public sentiment must be thoroughly aroused which will compel the passage and enforcement of better conservation laws.

235. Necessity for reforesting and for forest protection. Surely enough has been said to show the necessity for forest

Courtesy U. S. Forest Service

Fig. 208. — Fighting a forest fire

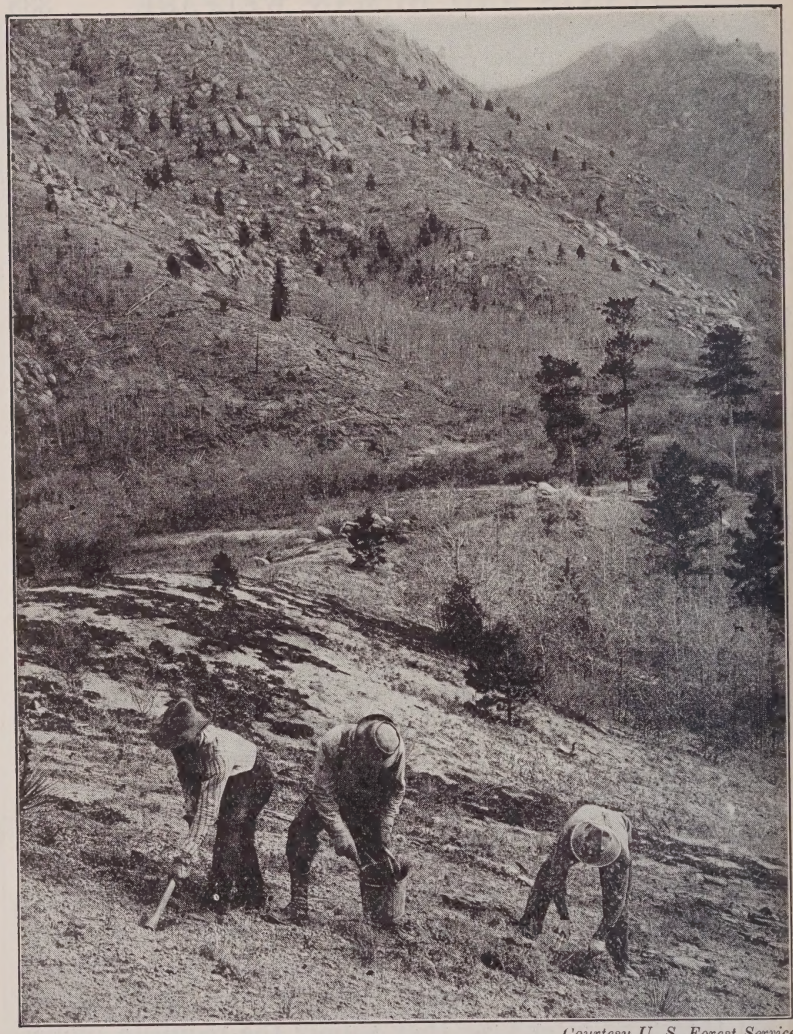
protection. Fortunately laws have been passed that enable the National and some of the State Governments to acquire large tracts of land for forestry purposes. In many states these forest areas will protect the sources of large streams. There is great need of trained experts to go through the forests, mark the trees which are mature enough to be cut, and decide what methods of cutting should be followed to

Courtesy Warren-Lamb Lumber Co.

Fig. 209. — Logging under State and Government restrictions

Note that the logs are carefully piled, the brush collected into heaps, and the young trees are left to grow.

keep the land producing trees for all time. Again, large areas already devastated should be replanted with young forest trees (Fig. 210). This is now being done to a considerable extent. In many foreign countries the forests are so used that year after year they supply the requisite timber and still continue to do their much-needed work in conserving the rainfall. Such must be the policy in our country if we wish to escape most disastrous penalties that always result from forest destruction.

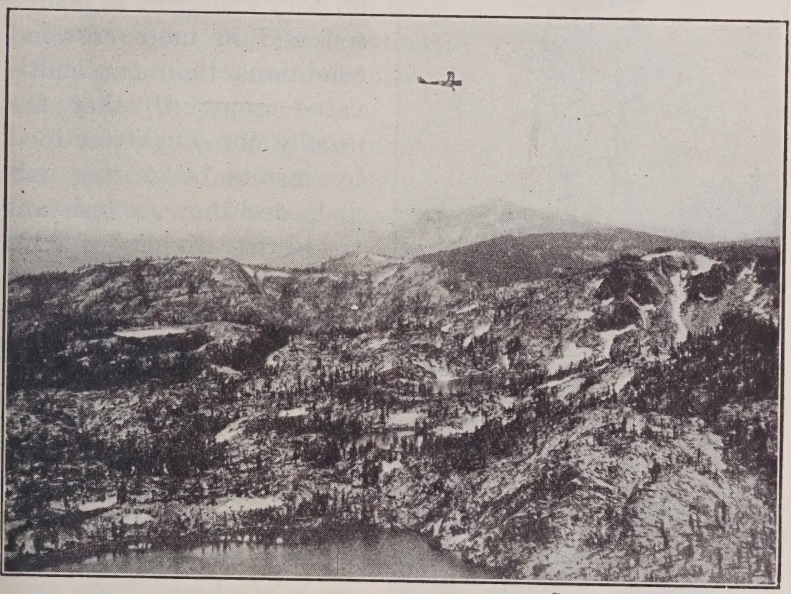


Courtesy U. S. Forest Service

Fig. 210. — Planting young trees

Areas that are unfit for cultivation can be made to yield profitable tree crops and at the same time help control the flow of water.

Another method of forest protection is that afforded by cutting trees in such a way as to form long treeless strips of land known as *fire lines*. Systems of telephone communication from one part of the Forest Reserves to another,



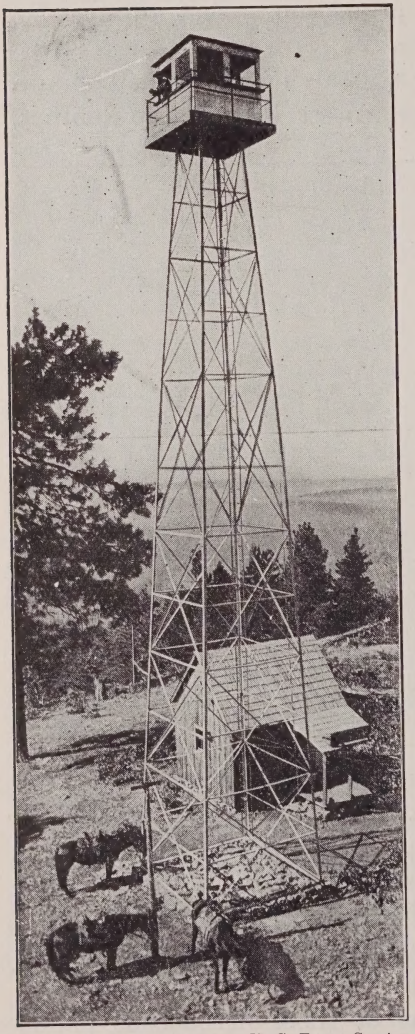
Courtesy U. S. Forest Service

Fig. 211. — Airplane watching for forest fires

fire wardens (Fig. 212), and airplanes (Fig. 211) are necessary factors in efficient protection of forests.

V. Plants That Are Injurious to Man

236. Weeds. Among the plants weeds are rightly regarded by man as injurious. The Century Dictionary defines a weed as "Any one of those herbaceous plants which are useless and without special beauty, or especially which are positively troublesome." Some of the characteristics of plants of this kind, which make them difficult to



Courtesy U. S. Forest Service

Fig. 212. — A forest lookout

The fire warden watches for fires from a tower on a mountain top.

contend with, are these: (*a*) They can usually resist extremes of temperature; (*b*) they can endure drought; (*c*) they can grow in poorer soil and in more crowded conditions than can cultivated crops; (*d*) they are usually not sought for food by insects or grazing animals, and they are resistant to plant diseases; and (*e*) they produce enormous numbers of seeds which often, as in milkweed, cocklebur, and thistle have most efficient provisions for seed dispersal.

The introduction into our country of many of these weeds is due to the fact that seeds of these plants were imported from Europe mixed with the seeds of grains. Finding, as did the English sparrow (**299**) and the gypsy moth (**257**), unusually favorable conditions for propagation here, these immigrants have often spread over large areas and have brought great damage to cultivated crops. Among the worst of our

weed enemies we may name black mustard, tumbleweed, pigweed, ragweed, and various certain types of grasses. To keep them in check the farmer must cultivate and hoe his crops frequently. In a way, however, this is advantageous to the plants, since it keeps the soil stirred up and thus insures a better supply of air and moisture about the roots.

Poison ivy (Fig. 213) is a plant that should be familiar to everyone since ivy poisoning, though seldom fatal, is perhaps one of the most uncomfortable experiences of the dweller in the country or of the visitor from the city. When one sees a woody vine trailing over the ground or clinging to trees by rootlets, *bearing compound leaves composed of three leaflets*, and in the autumn loaded with bunches of berries, however attractive the coloring may be — *beware!* For to touch this plant or even to come near it means for some people a distressing irritation of the skin and the formation of blisters. The poisonous effect of this plant seems to be due to a volatile oil formed in the leaves and stems. An effective treatment for ivy poisoning is an application of salt or a sugar of lead solution to the irritated parts.

From Sargent's Plants and Their Uses

Fig. 213. — Poison ivy

Note the number of leaflets in each compound leaf.

237. What substances injurious to man plants produce. *Opium*, of which *morphine* is an ingredient, is obtained from a thick, milky juice that comes from the fruits of the poppy

(Fig. 64), and *laudanum* is made by dissolving opium in alcohol. These substances are used in medicine to relieve pain. Unfortunately opium is widely used, especially among Eastern nations, for smoking. It is universally agreed that opium smoking and the injection of morphine beneath the skin are demoralizing, degrading, and pernicious habits, and that victims of the habits are sufferers both in body and in mind.

Fig. 214. — The edible field mushroom

Certain of the *mushrooms* are poisonous. These forms are commonly known as *toadstools*, but this is merely a popular distinction. In appearance and general structure poisonous and edible mushrooms are much alike. It is impossible to give any general directions that will help the student distinguish the edible (Fig. 214) from the poisonous mushrooms.[1]

238. Plants injurious to food materials or to other useful plants. The housewife is familiar with the fact that, if bread or cake is left for a time in a moist atmosphere, it is likely to mold. *Molds* (Fig. 215) are of many kinds, but all of them are low forms of plants that, like bacteria, feed upon common food materials and produce spores that escape into the air. To prevent the growth of molds, one should keep foods in a dry place.

Still another difficulty that confronts the careful housewife is

[1] A colored chart prepared by Dr. W. A. Murrill of the N. Y. Botanical Garden, Bronx Park, gives very clear pictures of the most common edible and poisonous fungi. See also Atkinson's *Edible and Poisonous Mushrooms.*

that of keeping preserves and other sweet substances from fermenting, or "working" — a process in which alcohol and carbon dioxid are produced. Fermentation is due to single-celled *yeast plants* (Fig. 216) that in their life processes change sugar to alcohol and carbon dioxid. Yeasts are killed by a boiling temperature; hence foods that have been heated sufficiently and sealed from the air while hot will not ferment.

Those of us who live in the eastern United States are only too well aware that our splendid chestnut trees have all been killed. This is due to a kind of fungous plant that destroys the living layer (*cambium*) between the bark and the wood. Scientists have been utterly unable to check this plant disease. The white-pine blister is another disease threatening our timber supply.

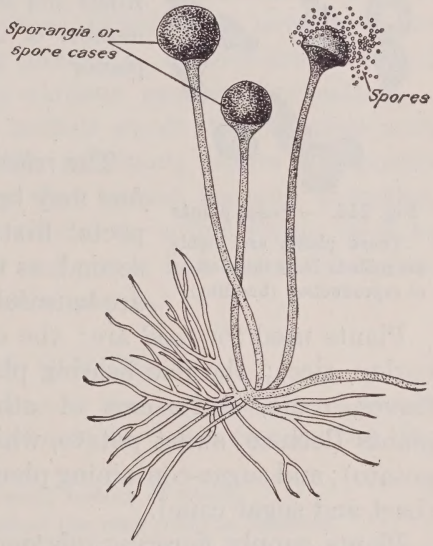


Fig. 215. — Bread mold
Appearance under the high powers of the microscope.

Rusts and smuts. The fungi known as *rusts* receive their name from the rusty appearance, in an early stage of their growth, which they give to the stems and leaves of affected plants. The cereals — wheat, oats, barley, and rye — are the crops which these fungi injure most. In the case of wheat half of the crop or even more may be destroyed.

The very suggestive name *smut* is given to another fungus which affects all the cereals named above and corn (Fig. 217) as well. The name is given on account of the appearance of the mass of black spores. If one touches these spores, especially those of corn smut, with the finger and then rubs the finger on some white paper or cloth, a sooty mark is left. The damage

done by smuts is very considerable. In case of the corn crop alone it has been estimated that a yearly loss of 20 per cent of the crop, or $20,000,000, is caused thereby, and in the other cereal crops the loss is even greater. Rusts and smuts are only two of a large number of fungous diseases that affect plants

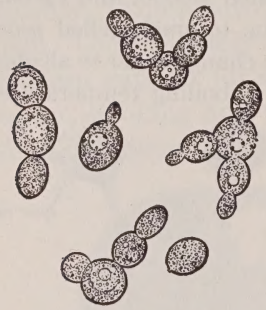


Fig. 216. — Yeast plants
These plants are highly magnified. Note the method of reproduction (budding).

Summary

The *relation of plants to human welfare* may be considered from two aspects: first, as to their uses to man; second, as to the ways in which they are harmful.

Plants used for *food* are: the cereals (wheat, corn, oats, barley, rice); the pod-bearing plants (bean and pea); the leaves, roots, and stems of other plants (lettuce, sweet potato, white potato); and sugar-containing plants (beet and sugar cane).

Plants supply *flavoring substances* (vanilla, pepper, mustard, allspice); plants furnish *drugs* (quinine, camphor, and the narcotics, such as belladonna, atropine, cocaine, and nicotine). From plants come materials for *clothing* (cotton from fibers attached to the cotton seeds; linen from the stems of the flax plant).

Fig. 217. — Corn smut

Forests supply *fuel* and *lumber*. Lumber has a great many uses. Forests *regulate the flow of streams* and *prevent erosion* of the soil. Forests

tend to *prevent floods and the filling up of rivers and harbors with soil.*

Dangers that threaten forests come from fires, insects, careless and ruthless lumbering, grazing flocks, and failure to provide for reforesting. *Reforesting* is necessary because the trees are being cut down faster than new trees are springing up or are being planted. Forests are protected from fires by fire lines, fire wardens, and airplane patrols.

Plants injurious to man include weeds that interfere with the growth of useful plants, poisonous plants like poison ivy, plants like the poppy that furnish harmful narcotics, poisonous plants that are similar to edible forms, such as certain of the mushrooms, and plants like the rusts, smuts, and bacteria that attack useful plants.

REVIEW QUESTIONS

1. From what two general points of view may plants be considered?
2. Name the cereal plants and state the various ways in which they are useful.
3. Tell what you can of the early history of wheat.
4. Give the history of the use of the corn plant in America.
5. Name the pod-bearing plants and show in what ways each is useful.
6. Enumerate plants the following parts of which are useful to man for food: the roots; the stems; the leaves; the flowers.
7. Of what country is the white potato a native? Why is it called "Irish"?
8. What are the sources of sugar? How is sugar prepared?
9. Name a number of fruits. How are fruits especially useful in the diet?
10. What plants are sources of beverages? Describe each of these plants.
11. Name some flavoring materials and the parts of the plant from which each is obtained.
12. Give the sources of several common drugs.
13. Tell the story of cotton and describe the enemies of the cotton plant.

14. State the sources of linen and describe the preparation of the fibers that make it.

15. Name other fiber plants and give the use of each.

16. Give an account of the uses of forests for fuel and timber.

17. Show why it is believed that forests help regulate the flow of streams and prevent floods and erosion of soil.

18. What are some of the dangers that threaten forests?

19. Why are reforesting and the protection of forests necessary?

20. Describe some of the means by which forests are protected.

21. Name plants that are injurious to man and state in what way each is injurious.

22. Name products obtained from plants that are injurious to man and state how each is injurious.

23. Name plants that are injurious to food materials; plants that are injurious to other plants.

CHAPTER XVIII

HOW FISHES ARE RELATED TO HUMAN WELFARE

I. Characteristics of Fishes

239. What a fish is. In the minds of many people *fishes* include a number of animals which even a superficial study shows can not be at all related to each other. Thus, for instance, animals as diverse as the jellyfish, starfish, shellfish (oysters and clams), and crayfish (Fig. 314) have nothing in common with real fishes except that they live in the water. Even whales (Fig. 17), seals (Fig. 302), and porpoises are regarded by those who are ignorant of natural history as belonging to the fish class, because these animals spend their lives in the water and in some cases resemble fishes in shape. The question now arises — What are the characteristics of a true fish? To answer this question we shall quote from one of the greatest authorities on fishes, Dr. David Starr Jordan.

"A fish is a backboned animal which lives in (that is, under) the water, and can not ever live very long anywhere else. Its ancestors have always dwelt in water, and likely its descendants will forever follow their example. So, as the water is a region very different from the fields or the woods, a fish in form and structure must be quite unlike all the beasts and birds that walk or creep or fly above ground, breathing air, and being fitted to live in it. There are a great many kinds of animals called fishes, but in this all of them agree: All have some kind of a backbone, all of them breathe their life long by means of gills, and none of

them have fingers or toes with which to creep about on land." [1]

When we apply these tests to each of the animals named in the first paragraph, we find every one lacks one or more of the characteristics we have enumerated. Thus, for instance, no jellyfish, starfish, shellfish, or crayfish has a backbone, even though all of them breathe by gill-like structures. Whales, seals, and porpoises, while they have backbones, never breathe by gills; instead, they must come to the surface to breath air by means of lungs.

240. Of what the regions and appendages of a yellow perch consist. One of the commonest fishes found in fresh

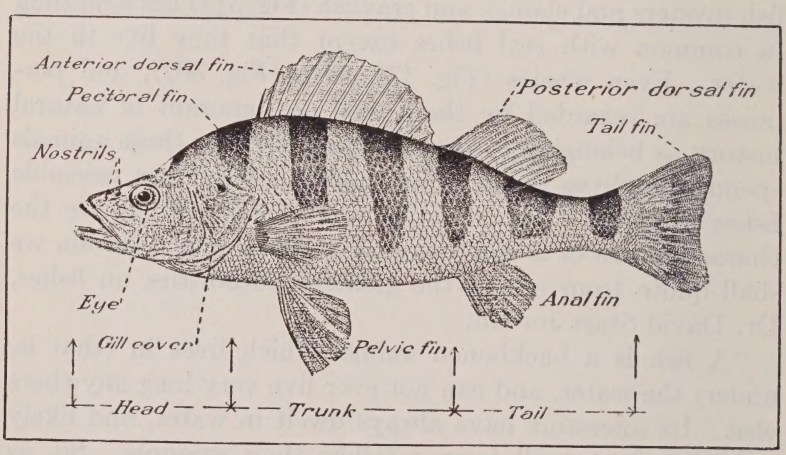


Fig. 218. — A yellow perch

water over a large section of the United States is the yellow perch. A study of Fig. 218 shows that the body of this animal is divided into three regions; namely, *head*, *trunk*, and *tail*. Unlike the body of many animals, no neck is present, and the head, therefore, is joined directly to the

[1] Jordan's *Guide to the Study of Fishes*, IX, 3.

trunk. The line of union is the hind margin of movable flaps, called *gill covers*, on the sides of the head. Just behind the gill cover on each side of the trunk is a paddlelike organ, called the *pectoral fin*. On the under, or ventral, surface, below the pectoral fins, is a second pair which are known as *pelvic fins*. The pectoral and pelvic fins are known as the *paired fins*. Besides these there are several *unpaired fins*. On the top, or dorsal, surface are two *dorsal fins*, one behind the other, which project upward. Below the hind dorsal fin, on the ventral surface, is another single fin, called the *anal fin*. The tail region is considered to begin just in front of the anal fin, since in the fish the body cavity that contains the important organs of digestion, circulation, excretion, and reproduction ends at this point. The anal fin, therefore, and also most of the posterior dorsal fin are attached to the tail region. At the posterior end of this third region is the broad, forked *tail* (*caudal*) *fin*.

EXERCISE 56

Study of the external structure of a goldfish. Laboratory study.

Materials: A living goldfish in a battery jar or small aquarium; if possible, one for each student. Goldfish may be kept indefinitely in a glass jar with green water plants. The latter supply the fish both with food and oxygen.

1. Compare the living goldfish with Fig. 218 of the yellow perch. What differences do you notice in the form of the fish and in the position and arrangements of the fins?

2. Make an outline drawing (about five inches long) with sharp lines of the side view of the goldfish to show the shape and relative size of the three regions, the position and shape of the organs of the head, and the various kinds of fins, in a manner similar to Fig. 218. Label each of the three regions of the body, the various organs found on the head, and the paired and the unpaired fins found on the body and on the tail.

241. How fishes carry on locomotion. Many fishes, like the goldfish and the perch, are able to maintain a given position

while they are at rest. This is made possible by means of an internal organ known as the *swim bladder* (Fig. 219). The swim bladder may be compressed, permitting the fish to sink, or it may be expanded, causing the animal to rise. Since, therefore, the fish is poised in a liquid medium, it is only necessary to overcome the resistance of the water about it in order to move in any direction. This resistance is more easily overcome, first, because the head is somewhat pointed like the prow of a boat; second, because the overlapping *scales* point backward; and, third, because

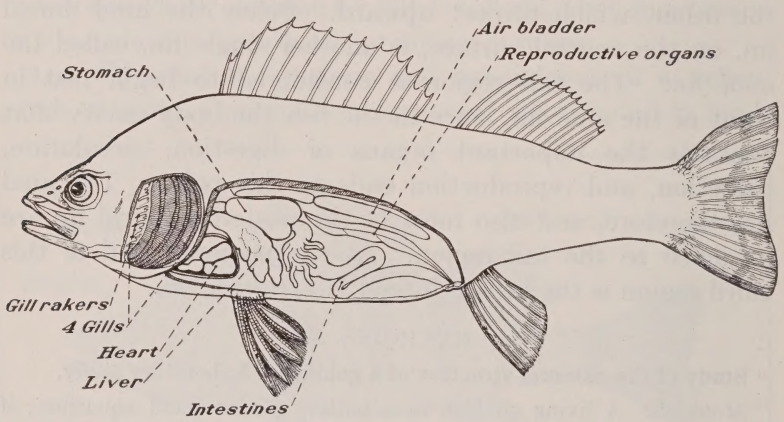


Fig. 219. — Internal organs of a perch
The body wall has been removed from the left side.

the whole body is covered with a slimy *mucus*, which enables the animal to slip through the water.

One who is at all familiar with a canoe knows that it is very difficult to propel it by the use of a slender rod. One must have a paddle with the lower end broad and flat so that sufficient force can be expended against the water to cause the canoe to move. This is likewise true of the fish. In swimming the fins of the fish act more or less like paddles. The broad, flat surfaces of these fins press against such an amount of water that the animal is enabled to exert force enough to push its body in any desired direction.

If one watches a goldfish[1] swimming slowly about in an aquarium, one would think that the paired fins, especially the pectoral fins, were the important swimming organs. But careful experiments have shown that this is not the case. When the goldfish has occasion to move more rapidly, the paired fins are not used at all but are pressed close to the sides of the body. In rapid locomotion the fish is driven by the movements of the tail and of the tail fin. The paired fins and the dorsal and anal fins seem to be used principally in steering the animal. The energy necessary for swimming is developed in the powerful muscles of the tail and trunk.

EXERCISE 57

How are the teeth of a fish adapted for food getting? Laboratory study.

Open the jaws of a fresh or of a preserved fish. (Fish of large size, *e.g.* bass or cod, should be used if possible, the jaws being held wide open with pieces of wood.) Look for teeth on the jaws and on the roof of the mouth.

1. State the location of the teeth and give some idea of their number.
2. Rub the fingers gently back and forth over the teeth. Do they point backward or forward? How do you know? Describe any other characteristics of the teeth.
3. Of what use would the teeth be in catching and holding other fish for food?

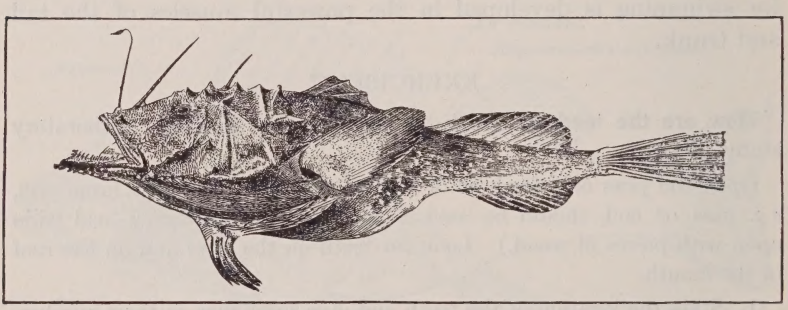
242. How fish are adapted for food getting. Unlike plants, fishes can not make their food from materials found in the water, soil, and air but must secure it ready-made in the form of plants and animals. The goldfish, for example, depends largely on vegetable food, while the cod[2] and the perch for the most part

[1] While studying this section, the pupils should watch the live goldfish when it is swimming both slowly and rapidly. Notice that each fin is composed of stiff *fin rays* and thin *connecting membranes* and can be spread out or closed up somewhat like a fan.

[2] "The cod is omnivorous, and feeds upon various kinds of animals, including crustaceans, molluscs, and small fishes, and even browses upon Irish moss and other aquatic vegetation. All sorts of things have been found in cods' stomachs, such as scissors, oil cans, finger rings, rocks, potato parings, corncobs, rubber dolls, pieces of clothing, the heel of a boot, as well as other new and rare specimens of molluscs and Crustacea." — Jordan and Everman's *American Food and Game Fishes.*

feed upon other animals smaller than themselves. Since these fishes must catch and hold their prey, their jaws are provided with many sharp teeth that point backward and so prevent the escape of any active animal which may have been caught. The cod has teeth in the roof of the mouth and in the throat in addition to those found on the jaws, thus making more secure its hold upon its prey.

Certain fishes subsist on minute forms of plants and animals, and therefore some means is needed by which the water taken in



Courtesy U. S. Fish Commission

Fig. 220. — Goosefish or angler

Note the lure bait projecting from the top of the head.

with the food may be gotten rid of, while at the same time the food is retained. Hence, fishes are provided with a straining apparatus on the floor and the sides of the mouth cavity, which permits the water to escape when the mouth is closed. This retains within the mouth the minute forms of life that it has secured. Of this adaptation for food getting, we shall learn more in our study of the gills.

Most of the fishes that prey on other animals secure their victims by dint of their speed. Some of them, however, are provided with lures (Fig. 220) that may be luminous organs, or tufts of filaments. Some fish have a color or pattern of coloration that serves to conceal them and permits their prey to approach without fear. Still others have means of wounding or disabling

their prey before taking it into their mouths. But whatever a fish feeds upon and however it secures its food, plants and other animals must furnish the food substances required to make living matter and to furnish the fuel needed to develop the energy for the various activities of the fish.

243. How a fish is adapted for digesting its food. In fishes, as in man, a portion of the body known as the digestive system is devoted to preparing the food for absorption and use. This digestive system consists of a food tube called the *alimentary canal* and certain groups of cells that form the *digestive glands*. When the fish swallows food, this passes from the *mouth cavity* into a short tube called the *gullet* and thence into a comparatively long and wide *stomach*, which in the perch extends half the length of the body cavity (Fig. 219). From the stomach extends the *small intestine* which turns upon itself several times, forming a coil, at the hind end of which is an opening to the exterior just in front of the anal fin.

In the inner lining of the stomach and intestine are digestive glands that have the power to manufacture digestive ferments and juices, which are poured out into the alimentary canal when food is present. These ferments make the foods soluble and ready for use in the body. In addition to the digestive glands in the lining of the alimentary canal, there is a large and very important gland that is situated outside the digestive tube. This gland is the *liver*, which secretes the bile. This is carried to the intestine by a tube called the *bile duct*. When the food has been digested, it is absorbed by thin-walled blood vessels (capillaries) found in the lining of the alimentary canal; and so the food passes into the blood to be distributed to the various parts of the body.

244. Blood and circulation of blood in the fish. As in man, in the fish are *blood vessels* to distribute food and other materials to the working organs. A *heart*, which aids in keeping the blood in constant motion through the blood vessels, is also present. The blood vessels are of three kinds; namely, *arteries*, *capillaries*, and *veins*. The arteries have elastic walls which contract and so

aid the heart in forcing the blood along its course. The arteries, as in man, always carry the blood away from the heart, and they

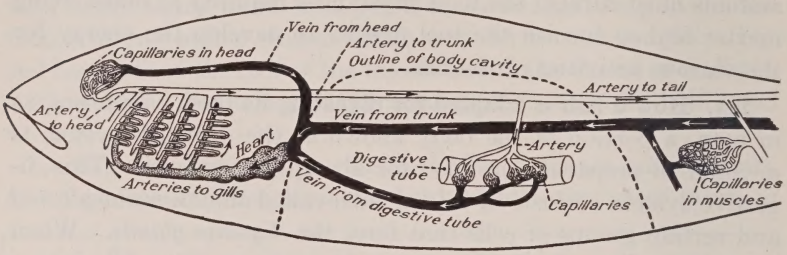


Fig. 221. — Circulation of blood in the fish

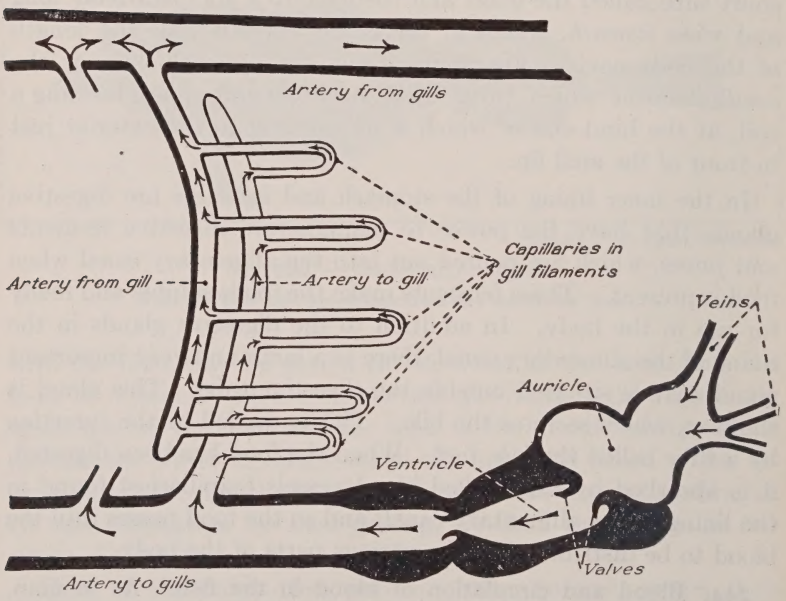


Fig. 222. — Circulation to, through, and from the gills

This figure is an enlarged drawing of the heart and of one of the four gills shown in Fig. 221.

subdivide into smaller and smaller tubes. At the ends of the smallest arteries are tiny, short, thin-walled blood vessels, the

capillaries. These permit the digested food to diffuse through their walls into the adjacent cells and absorb waste matter from the cells into the blood (Fig. 221).

The blood passes from the capillaries into the veins, which are thinner-walled than the arteries. The veins carry the blood back to the heart. The heart, unlike that of man, consists of only two principal parts: a thin-walled receiving chamber, the *auricle,* which takes in the blood brought by the veins, and a thick-walled, muscular portion, called the *ventricle,* which forces the blood out into the arteries (Fig. 222).

EXERCISE 58

How is the fish adapted for breathing? Laboratory study.

1. Raise the *gill covers* of a fresh or preserved fish and find the *gills.* Carefully separate the gills with forceps. How many gills are present on each side?

2. The openings between the gills are called *gill clefts.* Gently push a thin strip of wood or forceps through one of the gill clefts as far as you can.

a. In what cavity do the forceps or the strip of wood appear?

b. Describe the situation of the gills with reference to the mouth cavity.

3. Place a gill that has been removed from a perch or other good-sized fish in a watch glass and cover it with water. Find the following parts: (1) a soft part made up of slender divisions called *gill filaments;* (2) a curved part to which the filaments are attached, known as the *gill arch;* and (3) projections on the side opposite the gill filaments, which are known as *gill teeth,* or *rakers.*

a. Is the gill arch relatively hard or soft compared to the filaments?

b. Are the gill teeth, or rakers, relatively hard or soft?

c. Look again at the perch or other fish and state whether the rakers are found on the side of the arch nearest to the mouth cavity or on the opposite side. What would be the use of the gill teeth when the fish takes in a mouthful of water containing food and does not wish to swallow the water?

d. Make a sketch (natural size) of a gill. Label the gill arch, gill filaments, and gill rakers.

4. Note (to be copied). The gill filaments contain thin-walled blood vessels (capillaries) which are separated from the water only by a thin membrane. The heart forces the blood into certain arteries that carry it to the capillaries of the gills. Thence blood is sent through another set of arteries to the various parts of the body. After passing through another set of capillaries the blood is returned to the auricle of the heart through the veins.

5. Bearing in mind that respiration is essentially the same in all animals and plants, answer the following:

a. What gas will the blood bring from the body to be given off through the gill filaments in the process of breathing?

b. What gas is taken up by the blood in the gills to be carried through the body?

c. How are the gill filaments fitted by structure to permit this interchange of gases?

d. How are the delicate gill filaments protected from injury?

6. If the same water remained over the gills for some time, what changes in the relative amounts of oxygen and carbon dioxid in the water would occur? Why, then, is it necessary that a current of water should pass over the gill filaments?

7. Describe the movements of the jaws and gill covers of a living goldfish when it is breathing. (If the fish has been in a jar of water without green plants or fresh water for some time, these movements will be more pronounced.)

8. Watch the fish as it opens its mouth.

a. Is the size of the mouth cavity now greater or less than it was when closed?

b. Why does the water now enter the mouth?

c. What gas will this current of water bring to the gill filaments?

9. Watch the fish as it closes its mouth.

a. Is the size of the mouth cavity now greater or less than it was before?

b. What becomes of the water that was in the mouth cavity? Give your reason.

c. What gas will the current of water carry away from the gill filaments?

245. How respiration and the release of energy are accomplished by fishes. When the goldfish or other fish

takes in a mouthful of water and then closes its mouth, the water is forced over the gills, thus bringing oxygen to the numerous thin-walled filaments which spring from the gill arches (Fig. 222). The capillaries in the filaments absorb the oxygen, and the blood then passes on into the arteries[1], which carry it all over the body of the fish (Fig. 221). In the capillaries at the ends of the smallest arteries the oxygen passes into the cells as does the food. Now what becomes of the oxygen?

Since the proteins, fats, carbohydrates, and protoplasm all contain carbon, when any one of these is oxidized, carbon dioxid is formed as one of the waste substances. All the waste substances pass out of the cells through the walls of the capillaries into the blood, which passes on into the veins and so back to the heart. The heart contracts and drives the blood thus loaded with carbon dioxid out into the arteries. These conduct it to the capillaries of the gills, where the waste carbon dioxid passes out into the surrounding water, which is then forced out under the gill covers by the closing of the mouth.

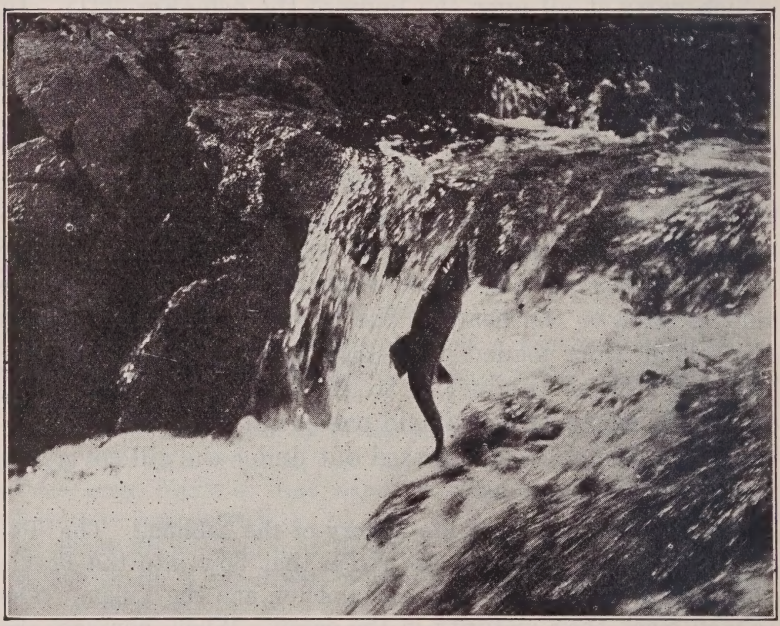
246. Reproduction and life history of the salmon.[2] The Pacific salmon are caught in the rivers that flow into the Pacific Ocean, such as the Columbia, Sacramento, and the Yukon. The salmon reach their maturity in the ocean. When, however, the spawning time approaches, the salmon make their way in great numbers to the mouths of the rivers. They then proceed up the streams, leaping seemingly impassable waterfalls to reach the headwaters (Fig. 223). Here on sand or gravel the female salmon deposits her eggs, and the male emits the fertilizing sperm cells. The fertilized eggs are then covered with sand or gravel and thereafter receive no attention from their parents. Indeed, the

[1] This is an unusual arrangement, due to the fact that the blood of fishes, after passing through the breathing organs (gills), circulates through the body before returning to the heart.

[2] For a general account of reproduction in fishes see 166–170.

parent fishes soon die; none of them ever reaches the ocean again. After the eggs hatch, the young develop slowly and finally go down the stream to the ocean to repeat the life of their parents.

247. Reproduction and life history of the common eel. Until recent years nothing was known concerning the marvelous life



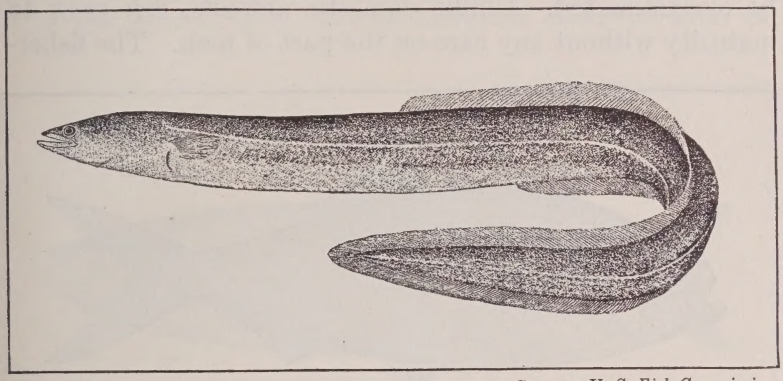
Courtesy U. S. Fish Commission

Fig. 223. — Salmon, jumping falls

history of the eel (Fig. 224). Even now there are gaps in our knowledge regarding the breeding habits of this fish in spite of the fact that young and mature forms have been known from ancient times. Upon reaching maturity the eels leave the fresh-water streams and seek the ocean to spawn. Hence their course to their spawning grounds is directly opposite to that of the salmon.

Concerning their egg-laying habits, however, we as yet know nothing beyond the fact that the eels of Europe and America

swim far out to the mid-Atlantic to deposit their eggs. We know this because the youngest eels are never found near land or anywhere near the mouths of rivers which they finally enter to complete their development. Young and larval eels have been collected by means of fine-meshed towing nets from regions all the way across the north Atlantic from the latitude of Florida to



Courtesy U. S. Fish Commission

Fig. 224. — Common eel

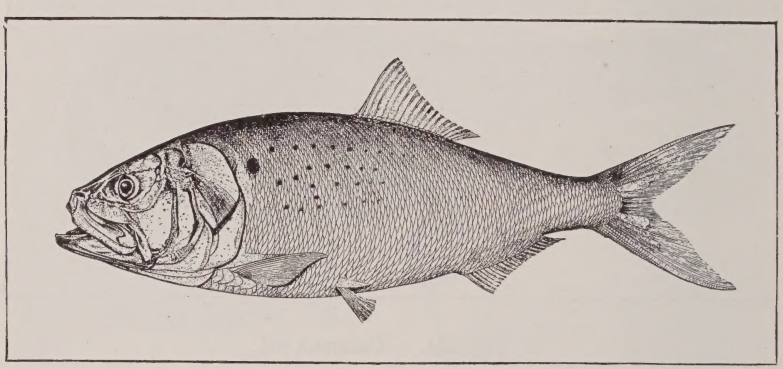
Maine. The youngest specimens, however, are found only in mid-ocean, especially between the Azores and Bermuda. From here they somehow make their way for a thousand miles or more, till finally they reach the mouths of rivers of Europe and America. This long journey requires several years. Yet during a portion of this period at least the young eels take no food whatever. Indeed, after attaining a certain size, they actually become smaller!

"Some eels remain in the lower parts of the streams and move back and forth in the bays and estuaries, and others press on to the headwaters, often surmounting obstructions that would be impassable for other fish, and remain there until full maturity is attained. The parent eels that go down into the sea for breeding never return to the rivers from which they set forth." [1]

[1] See *National Geographic Magazine*, Oct., 1913—"The Mysterious Life of the Common Eel," by Dr. Hugh M. Smith, formerly U. S. Commissioner of Fisheries.

II. The Relation of Fishes to Human Welfare

248. How fishes are related to human welfare. From very ancient times fishes have formed a considerable part of the food of peoples that lived near bodies of water. The importance to man of fishes as a source of food can hardly be overestimated. Unlike domestic animals, fish grow to maturity without any care on the part of man. The fisher-



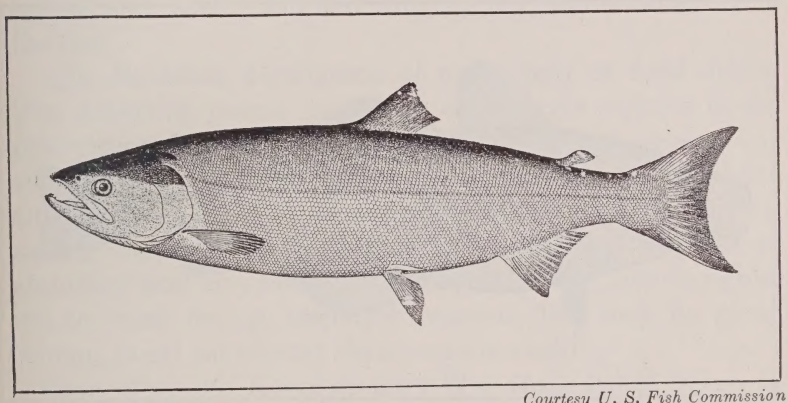
Courtesy U. S. Fish Commission

Fig. 225. — Menhaden

man has only to provide the means to gather his harvest, while the herdsman must care for his flocks and herds the year round. Thus we see why it is that fish should be a cheaper form of food than flesh of domesticated animals. Nearly all parts of fish are used as food. Not only is the flesh eaten, but also the eggs (roe) (Fig. 140). These animals furnish food either in a fresh condition or when prepared in various ways. Among these methods of preservation are drying, smoking, pickling, and canning.

While fish are important to man as a source of food, they have still other uses. Thus, for instance, the menhaden (Fig. 225) are caught scarcely at all for food but for the

large quantities of oil extracted from them. The remainder of their bodies is used as fertilizer, or after being dried and ground they are fed directly to cattle and to other domestic animals. It is estimated that about 3,000,000 gallons of oil and 1,000,000 tons of scrap, with a total value of $2,500,000 are obtained annually by American fishermen from this kind of fish. The oil extracted from the livers of



Courtesy U. S. Fish Commission

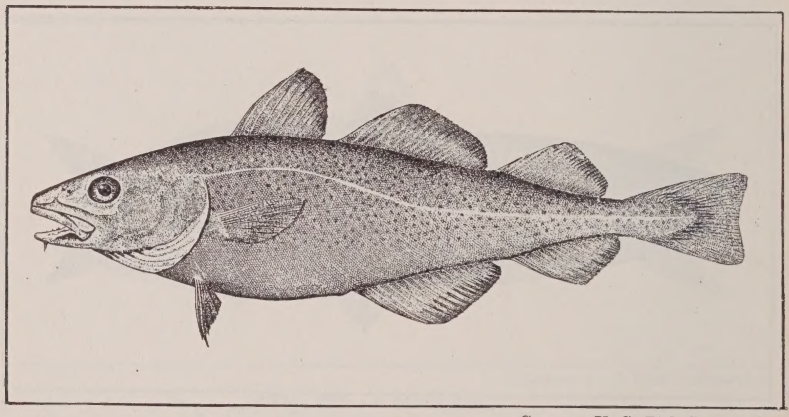
Fig. 226. — Pacific salmon

cod forms a valuable food preparation for invalids, since it is known to be more easily absorbed and oxidized in the body than any other known fat. The swim bladders of many fishes (*e.g.* sturgeon and cod), when dried, yield a high grade of gelatin.

249. How salmon and codfish are of importance to man. Salmon (Fig. 226) and herring are the most important food fishes of the world. The Pacific salmon, of which there are five species, is our most important fish. The Atlantic salmon, though once abundant, has disappeared from all the Eastern coast, save in the Penobscot River (see **250**).

Salmon is shipped fresh in ice. Enormous quantities are also smoked and salted. The catch of the Pacific salmon in 1920 was valued at about $40,000,000.

Next in importance to the salmon, at least in the United States, is the cod (Fig. 227), for which the fishermen receive annually about $3,000,000. Other countries engaged in the cod fishery are Newfoundland, Canada, Norway,



Courtesy U. S. Fish Commission

Fig. 227. — Cod

Note the three dorsal fins and the distinct lateral-line sense organ.

Sweden, Great Britain, France, and Japan. Codfish are found in the northern part of both the Atlantic and the Pacific Oceans and are usually caught at a depth of 150 to 500 feet. "From the earliest settlement of America, the cod has been the most valuable of our Atlantic coast fishes. Indeed the codfish of the Banks of Newfoundland was one of the principal inducements which led England to establish colonies in America, and in the records of early voyages are many references to the abundance of codfish along our shores. . . . So important was the cod in the early history

of this country that it was placed on the colonial seal of Massachusetts, and it was also placed upon a Nova Scotian bank note, with the legend 'Success to the Fisheries.'" [1]

The average weight of large cod is from twenty to thirty-five pounds. The average weight of small cod is twelve pounds. While cod weighing 75 pounds are not common, one was caught off the New England coast many years ago that weighed 211½ pounds. Cod is marketed fresh, pickled, salted, and dried. Oil and isinglass are also obtained from the cod.

250. Reckless destruction of our supply of food fishes. The American people have been exceedingly reckless in the destruction not only of our forests (234), but also of our resources of wild life on land and in the water. We have cited the way the Atlantic salmon has been nearly exterminated. More than a hundred years ago this fish was so abundant and so commonly used that young men in agreeing to work for an employer insisted that they be given salmon to eat no oftener than twice a week!

Soon after the Revolutionary War these fishes began to diminish rapidly, and in 1819 one writer states that the salmon had scarcely been seen in the Connecticut River for fifteen or twenty years. The principal reason for this was that high dams were built across the rivers, which prevented the fish from swimming up streams to their fresh-water spawning places. The Pacific salmon (Fig. 228) are rapidly decreasing in some localities. This is due to a considerable extent to the competition among the canning factories, each seeking to secure all of the fish that it can.[2]

[1] From Jordan and Everman's *American Food and Game Fishes.* Every student of this chapter on fishes should read Kipling's *Captains Courageous* for the description of the cod fisheries on the Grand Banks.

[2] See "America's Most Valuable Fishes" by Dr. Hugh M. Smith, in the *National Geographic Magazine*, May, 1919. This article also contains striking photographs of leaping salmon and of salmon traps and runways.

251. How our supply of fishes can be conserved. Many states have passed laws for the protection and conservation of game fishes, such as trout and bass. The sportsmen have seen to this; and while it is desirable that these forms

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Fig. 228. — Salmon catch

Enormous numbers of these fish are taken on the Pacific coast.

of wild life should be preserved and their number increased, it is of much greater importance that the fishes which supply food for millions should not be left without adequate protection.

The number of all fishes desirable for food should be increased by artificial propagation (Fig. 137), and wise

laws governing the catching of fish should be passed and rigidly enforced. The United States Government and various states have been doing splendid work in the artificial propagation and distribution of fishes through the agency of the fish-hatching stations of the Bureau of Fisheries and of the states. The regulation of the fish industry, however, has been left to the initiative of the states. The indifference or inability of the states in this matter may make Federal control desirable if this important source of our food supply is to be maintained.

The following are some of the regulations that many of the states have embodied in laws: (1) There must be no obstruction in rivers that would prevent fish from moving freely up and down streams either to spawn or to search for food. If dams are built, fishways must also be constructed permitting the free passage of fish. (2) Fish must be protected at the spawning season. (3) No methods of fishing must be employed in which large numbers of immature fish are caught or killed. Such methods are (*a*) exploding dynamite in the water, thus killing all kinds and sizes of fish indiscriminately; (*b*) catching fishes with nets the meshes of which are so small that immature fish are caught as well as mature; (*c*) wholesale and mechanical devices of catching fish, such as the fishing wheel, for by this device the fish have no chance for escape. (4) Fishermen must not keep fish even when caught if they are undersized. (5) It must be illegal to destroy wantonly any food fish or use it for any purpose other than food. (6) Waters in which fish live must be kept free from pollution.

These laws are enforced by State Fish and Game Wardens provided there is public demand for their enforcement. The necessity for the enforcement of these regulations will be obvious not only in waters over which the states have

jurisdiction but also in the waters controlled by the United States Government.

Summary

A *fish* is a backboned animal (vertebrate) that breathes throughout its life by means of *gills*. Its body consists of head, trunk, and tail. The outside surface of a fish is almost always covered with *scales*, upon which is slimy mucus.

Usually *paired fins* (pectoral and pelvic) and *unpaired fins* (dorsal, anal, and tail fins) are present. Rapid locomotion is carried on almost wholly by means of the tail and tail fin. The fish is enabled to rise or sink in the water by expanding or contracting the *swim bladder*.

Within the mouth cavity are *teeth* that usually point inward, thus enabling the animal to catch and hold its prey. On either side of the mouth cavity at the entrance to the gill chamber are the *gill teeth*, or *gill rakers*, which prevent the food from escaping through these openings.

When the fish opens its mouth, the water with its oxygen supply enters the enlarged mouth cavity. When the mouth is closed, the muscular walls force the water out through the *gill clefts* on either side. In this way the blood in the capillaries in the *gill filaments* is supplied with oxygen and rids itself of waste carbon dioxid. The energy of the fish is a result of the union of oxygen with the food substances in the process of oxidation.

Fishes are of great value to man as a source of food. Since they require no care fish should be less expensive than other animal foods. Herring, salmon, and cod are the most important food fishes, and in the order named. They are eaten fresh, dried, salted, or pickled. Fish are also used for oil (cod, menhaden) and for fertilizer (menhaden).

The Atlantic salmon has been nearly exterminated because dams were built that kept the fish from their spawning grounds. Sewage that is allowed to enter rivers has caused the destruction of certain fish (*e.g.* the shad in the Hudson River).

In order to maintain our fish supply it is often necessary to breed them in fish hatcheries. Laws must be enforced to prevent overfishing, especially during the breeding season, and to protect the young fish until they have reached maturity.

REVIEW QUESTIONS

1. How does a fish differ from all other forms of animal life?
2. Mention six animals commonly spoken of as "fishes" and show why each is not a fish.
3. Name the regions of the body of a yellow perch. State where each region begins and where it ends.
4. Name, locate, and give the number of each kind of fin found on the yellow perch. How do the fins of a goldfish differ from those of a perch?
5. Describe the structure of a gill. How are the gills supplied with fresh water?
6. What changes take place in the composition of the blood (1) in the gills, (2) in the working tissues?
7. Why are fish such an important source of our food supply? In what ways are fish preserved until they are eaten?
8. Give some idea of the value of the salmon fishery; of the cod fishery.
9. In what ways, other than as a source of food, are fish of importance to man?
10. Give an account of the extermination of the Atlantic salmon. Name other fish that are in danger of being killed in too large numbers.
11. Describe each of several steps that should be taken to protect our supply of fish.

CHAPTER XIX

HOW INSECTS ARE RELATED TO HUMAN WELFARE

I. Butterflies and Moths

EXERCISE 59

Study of a butterfly. Laboratory study.

Materials: Mounted butterflies (if possible in glass cases) with sucking tubes uncoiled; live butterflies in cages; pieces of wings for microscopic study.

A. Regions and appendages: Examine a butterfly and distinguish (*a*) the front, or *anterior*, region, called the *head;* (*b*) the middle region, called the *thorax;* and (*c*) the hind, or *posterior*, region, known as the *abdomen.*

1. Name and locate the three body regions.

2. Which region is the smallest? Which is the widest? Which region is the longest?

3. To which region are the legs and wings attached? (These organs are known as *appendages.*) What other region has other kinds of appendages?

4. Which region seems to have no appendages?

B. Organs of the head; feeding.

1. Observe two long, slender appendages attached to the head; they are called *antennæ* (singular, *antenna*). State the position of the antennæ on the head and describe their shape, stating which end is the thicker.

2. Near the base of the antennæ find the *eyes.* State their position on the head, their shape, and their size (as compared with the rest of the head).

3. Study a prepared specimen with the sucking tube uncoiled, or uncoil the tube in a living or in a relaxed specimen. Describe the position and appearance of this feeding organ.

4. (Demonstration by the teacher.) Dip a dissecting needle in a drop

of honey or molasses diluted with water, put the needle into the coil of the sucking tube of a live butterfly, and gently unroll the tube.

a. Describe what is done.

b. Watch the size of the drop; what reason do you find for believing that the butterfly is feeding?

C. Organs of the thorax; locomotion.

1. How many pairs of wings has the butterfly?

2. Compare the length and breadth of the wings. What can you say concerning their thickness?

3. Hold a butterfly between yourself and the light and study carefully the course of the veins in the two wings on one side. Toward what part of each wing do the veins converge?

4. Take a small piece of the wing of a butterfly and rub the surface with your finger tip.

a. Describe what you have done and compare the color of the substance on your finger with the color of the part of the wing before it was rubbed. To what therefore is the color of the wing due?

b. Shake some of the powder from a wing upon a glass slide and examine it with a low power of the compound microscope. The bodies that you see are *scales*. At one end is a tiny stem by which the scale is attached to the wing, and at the other end usually one or more notches. Make a sketch (much enlarged) of one of the scales.

5. Examine the legs of a butterfly. (Some butterflies have a tiny pair of front legs that are usually folded against the thorax; so you will need to look very carefully before deciding as to the number of legs.)

a. How many pairs of legs has this insect?

b. Are the legs long and slender or short and thick?

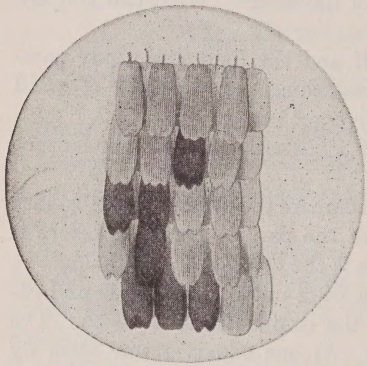
c. Is each leg all one piece or is it made up of sections with joints?

d. Examine the lower end of a leg (foot) with a magnifier and describe what you find. How is the butterfly adapted for clinging to plants?

6. Make a drawing (natural size) of the upper surface or the side of a butterfly. Label antennæ, eyes, sucking tube, head, thorax, abdomen, wings, and course of the veins of one wing.

252. A comparison of butterflies and moths. Butterflies and moths belong to the same group of insects, which is known as Lepidoptera (from the Greek, meaning *scale-winged*), so called be-

cause their wings are covered with microscopic scales. These scales are attached to the wings thus: In the membrane of the wings are minute pockets into which fit the stems of the scales. The latter are usually arranged in rows and overlap somewhat like the shingles of a roof (Fig. 229). The scales, however, are not firmly attached since the slightest touch is sufficient to dislodge many of them. Rough handling was not apparently planned for in the construction of these insects. When the scales are rubbed off, the color of the wings and a certain amount of their rigidity disappear. Not only are the scales found on the wings, but, in the shape of hairs, they form a fuzzy growth over the surface of the rest of the body.



Courtesy American Museum of Natural History

Fig. 229. — Scales on a butterfly's wing

Photographed through a compound microscope; highly magnified.

Moths are distinguished from butterflies in the following ways: Moths when at rest hold the wings horizontally, while butterflies hold them vertically, that is, erect. The wings of moths are not usually as brilliantly colored as are those of the butterflies. Most moths fly at night while butterflies are day flyers. The bodies of moths are usually relatively broader than those of butterflies. Moth antennæ are of various shapes, often like feathers, but never knobbed. Moths in many cases form cocoons; butterflies never do.

253. Reproduction and life history of butterflies and moths. The development of the butterfly begins with a special cell known as an *egg cell*. These egg cells are formed in the body of the female. When these egg cells have been fertilized by *sperm cells* from the male butterfly, the eggs are deposited on the under side of the leaves of plants on

which the young can feed (Fig. 230). These egg cells divide and subdivide till at last a many-celled organism is developed that is often called a "worm" but more correctly is known as a caterpillar.

The tiny caterpillar emerges from the covering of the egg (that is, it hatches) and begins to feed upon the leaf. As it feeds, it grows; and from time to time it sheds, or *molts*, the more or less hardened skin that covers the whole insect. At last after several molts the caterpillar reaches its full size and then stops eating. At no time in the growth of the caterpillar could it be mistaken for a butterfly. It has no wings, no antennæ; and instead of a sucking tongue, one finds a pair of strong jaws with which it eats leaves. The distinction between thorax and abdomen is not at all clear, and at first sight it seems to have more legs than does a butterfly. Only the three front legs, however, are jointed, but they are so short and thick that there seems to be no resemblance between them and those of a butterfly. The other pairs of legs, varying in number, are not jointed structures and hence are not really legs at all (Fig. 230).

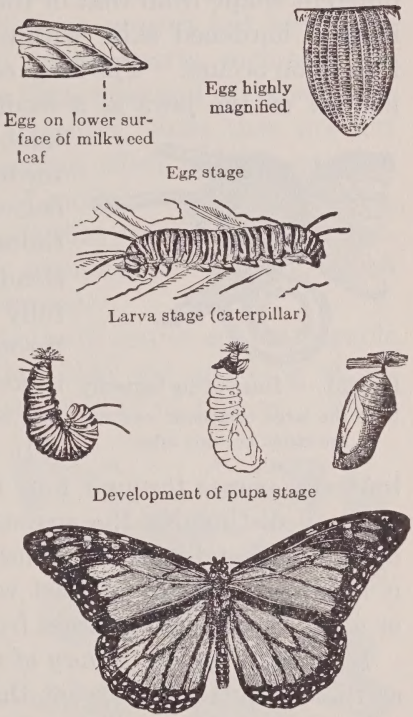


Fig. 230. — Life history of the monarch butterfly

The mature caterpillar now attaches itself to some object and, after molting once more, usually assumes quite a different shape from that of the caterpillar and forms about itself a hardened skin, within which a marvelous transformation occurs. The long, coiled tube appears (Fig. 231), instead of the jaws as a feeding organ and long, slender, knobbed antennæ are formed on the head. Two pairs of beautifully colored wings develop on the thorax as do the three pairs of slender, jointed legs. At last the fully developed butterfly breaks through the covering that holds it; and after its wings are pumped full of air and dried, it flies away.

Fig. 231. — Head of the butterfly Note the large compound eye and the coiled sucking tube.

It is evident then that the butterfly passes through four fairly distinct stages. First we may distinguish the *egg* stage, then the caterpillar, or *larva*, stage, and later the transformation stage during which it is called a *pupa*.[1] At last we have the fully developed, or *adult*, insect that emerges from the pupa stage.

In general the *life history of moths* is very much the same as that of butterflies except that the larvæ of many moths spin a more or less silky covering of threads about themselves as does the silkworm caterpillar (Fig 238.). This outside covering of the pupa stage is known as a *cocoon*. Hence a moth pupa is usually doubly protected: first, by the hard shell that forms, like that in butterflies; and, second, by the tough silken cocoon.

254. What relationship butterflies and moths have to human welfare. The larvæ of both butterflies and moths

[1] The pupa of a butterfly is often called a *chrysalis* (from the Greek, meaning *gold*) on account of the golden spots of color on many pupa cases.

are voracious feeders as anyone knows who has had any experience with caterpillars. In fact they may be called animated feeding machines since the animal in this stage must not only provide for its own growth but must also store up enough food to form the new parts, such as wings and legs. The larvæ of many butterflies and of some moths are not considered harmful, however, since they are not prolific enough to have any serious effect upon vegetation, which is the source of food of most caterpillars. Indeed, some of the larvæ feed on plants that are not useful to man. This is true of the monarch, or milkweed butterfly, which feeds on the leaves of the milkweed.

The adult butterflies and moths of course are not capable of doing any harm since, when they eat anything at all, they most commonly suck the nectar of flowers. When the flowers are visited in this way, they are very likely to be cross-pollinated and thus are benefited instead of injured. But in general the moths and butterflies play but little part in the very important process of cross-pollination, most of this work being done by the bees. The following are a few of the injurious forms of butterfly and moth larvæ.

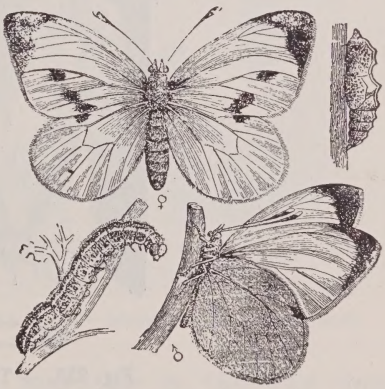


Fig. 232. — Cabbage butterfly
Larva, pupa, male (below), and female (above).

255. Cabbage butterfly. This is one of the few forms of butterfly larvæ that are of sufficient economic importance to be worthy of mention. Anyone who has been near a cabbage patch may have seen many rather small white butterflies (Fig. 232) hovering

about among the cabbages. These are cabbage butterflies depositing their eggs on the under side of leaves. The small green caterpillars that develop from the eggs very soon show what they can do in the way of eating. The ragged appearance of the young

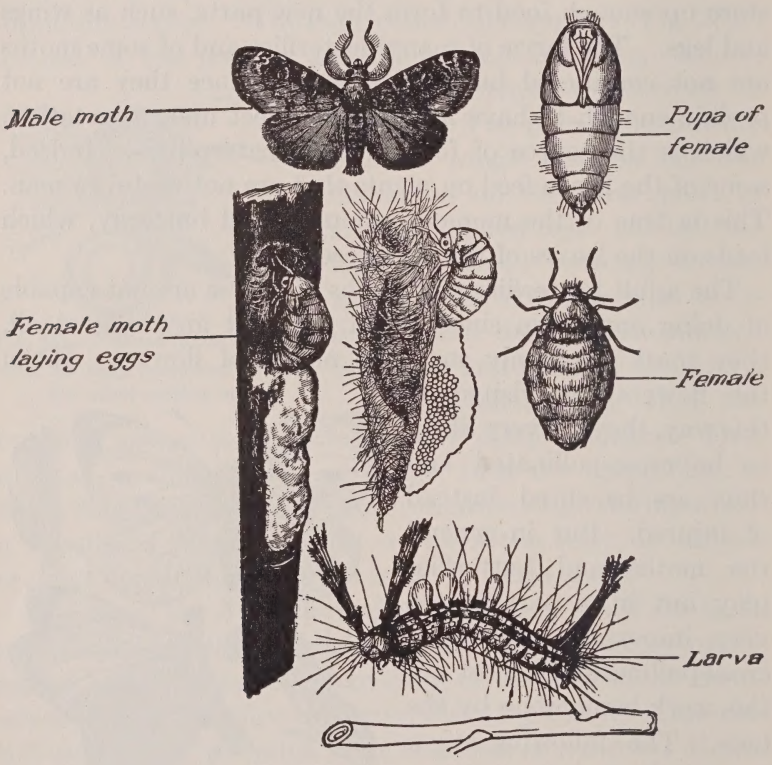


Fig. 233. — Tussock moth

leaves is a warning to the gardener to "get busy" if he desires a crop. The caterpillars do most harm when the cabbages are young since these plants may be so injured as to be unable to form heads. The caterpillars are often killed by being poisoned with a mixture of arsenate of lead in water which is sprayed on the young plants.

256. Tussock moth. The caterpillars of the tussock moth attack our shade trees. Where they are unchecked, they will practically strip the trees of their leaves. The female moth is wingless (Fig. 233). When she emerges from her cocoon, she lays a mass of eggs upon the outer surface of the cocoon and secretes about them a white foamy mass which soon hardens. If this occurs in the autumn, the eggs remain during the winter and the following spring hatch out. The young caterpillars attack the leaves of the tree where they hatched; or if the cocoon was placed elsewhere, they crawl up the nearest tree and start business at once.

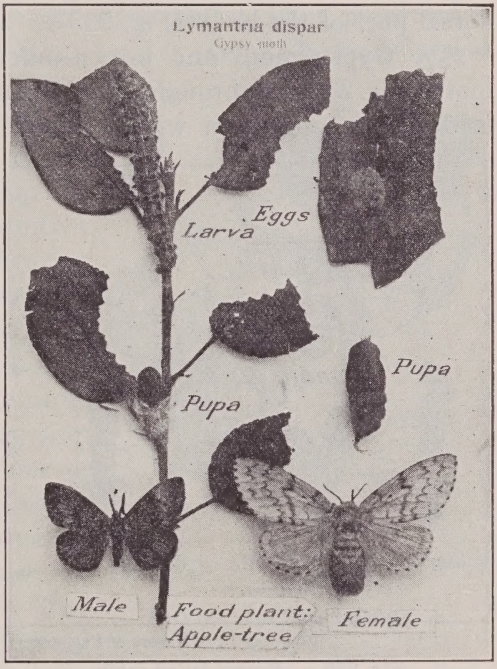
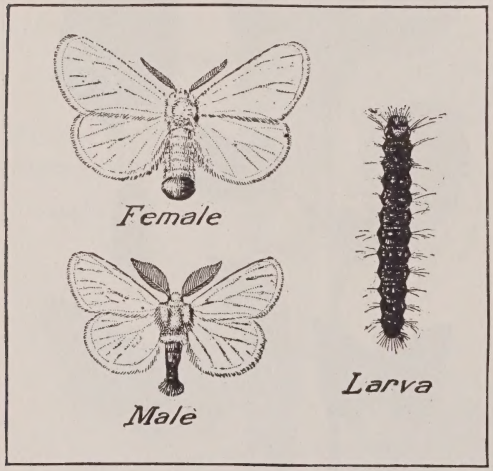


Fig. 234. — Life history of the gypsy moth

They are great travelers, and this is the way they spread through a neighborhood since the female can not fly. To capture these insects one may place a band of cotton batting around the trunk of each of the trees one wishes to protect. The larvæ do not usually crawl over this but will, if mature, proceed to pupate underneath the band. All pupæ and egg masses should be collected and then

burned. This is about as much as the individual can do. Where a spraying apparatus is available, the trees should be sprayed with lead arsenate to kill the caterpillars. This caterpillar is rather handsome as caterpillars go, having a bright-red head and a series of yellow tufts of hair on the dorsal part of the body (Fig. 233).

257. Gypsy moth and brown-tailed moth. The gypsy moth (Fig. 234) was brought into Massachusetts from Europe in 1869 in connection with scientific experiments. Some of these specimens accidentally escaped and gradually increased until the damage to fruit, forest, and shade trees caused by the larvæ was so evident that property owners had to call upon the state to aid in their extermination. Nearly one million dollars was expended during a period of ten years. At the end of this time the number of the insects was so reduced that it was impossible to convince taxpayers of the necessity for further appropriations to complete the extermination. Since then the gypsy moths have spread over all the New England States and into the adjoining states.



Courtesy U. S. Bureau of Entomology

Fig. 235. — Brown-tailed moth

The larvæ of the brown-tailed moth have likewise caused great damage in the New England States (Fig. 235).

258. Codling moth. Everyone has eaten into apples that have been injured by the "apple worm," which is the larva of the codling moth (Fig. 236). The damage to the fruit crop from this insect in the United States in 1909 is estimated at sixteen million dollars. According to Professor Hodge (*Nature Study and Life*) the codling moth "was early imported from Europe and is now at home wherever fruit is cultivated in this country and Canada, causing a loss of from 25 to 75 per cent of the apple crop, as well as that of many other fruits. In the heavy bearing years the wormy apples fall off and are discarded, but the great number of apples serves to rear enormous numbers of the worms, and, according to my observations and experience, in the off years, when apples would be valuable, the worms take the whole crop." The practice of most commercial growers at the present time is to depend very largely or entirely on spraying with a poison, arsenate of lead. One application, even a week or ten days after the blossoms fall, if thorough, will frequently give 95 per cent to 98 per cent of sound fruit since in this way the larvæ developing in the young fruit are likely to be killed.

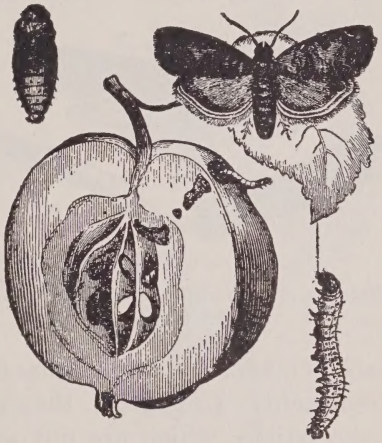


Fig. 236. — Life history of the codling moth
Note the harm done by the larva.

259. Clothes moths. "The little buff-colored clothes moths (Fig. 237) sometimes seen flitting about rooms, attracted to lamps at night or dislodged from infested gar-

ments or portières, are themselves harmless enough, for their mouth parts are rudimentary and no food whatever is taken in the winged state. The destruction occasioned by these pests is, therefore, limited entirely to the feeding or larval stage. The killing of the moths by the aggrieved housekeeper while usually based on the wrong inference that they are actually engaged in eating her woolens is, nevertheless, a most valuable proceeding because it checks, in so much, the multiplication of the species which is the sole duty of the adult insect.

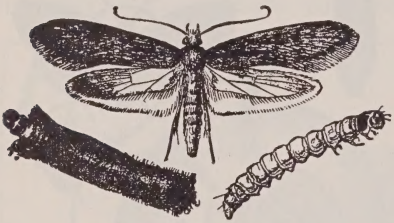


Fig. 237. — Clothes moth
Note the case formed by the larva from a woolen fabric.

"There is no easy method of preventing the damage done by clothes moths, and to maintain the integrity of woolens or other materials which they are likely to attack demands constant vigilance with frequent inspection and treatment. In general, they are liable to affect injuriously only articles which are put away and left undisturbed for some little time. . . . Agitation, such as beating and shaking or brushing, and exposure to air and sunlight, are old remedies and still among the best at command. Various repellents, such as tobacco, camphor, naphthalene cones or balls, and cedar chips or sprigs, have a certain value if the garments are not already stocked with eggs or larvæ. . . . Furs and such garments may be stored in boxes or trunks which have been lined with the heavy tar paper used in buildings. New papering should be given to such receptacles every year or two." [1] A compound called dinitrobenzol placed in trunks will kill all stages of the insect.

[1] *Circular No. 36, Second Series*, United States Department of Agriculture.

260. Silkworms. One species of moth, the silkworm (Fig. 238), is of great value to man. The larva of this insect feeds upon the leaves of the mulberry tree, and after reaching maturity it spins a cocoon requiring about three days for its completion. The silk, obtained by heating the cocoons in ovens to kill the pupæ, is then reeled off and spun into threads. "For many hundreds of years the cultivation of the silkworm was confined to Asiatic countries. It seems to have been an industry in China as early as 2600 B.C. and was not introduced into Europe until 530 A.D. After the latter date the culture rapidly increased, soon became prominent in Turkey, Italy, and Greece, and has held its own in those countries, becoming of great importance in Italy. . . . Japan to-day produces a very considerable proportion of the world's supply of raw silk." [1] Many attempts have been made to introduce this industry into the United States, but the experiments thus far made have been rather unsuccessful.

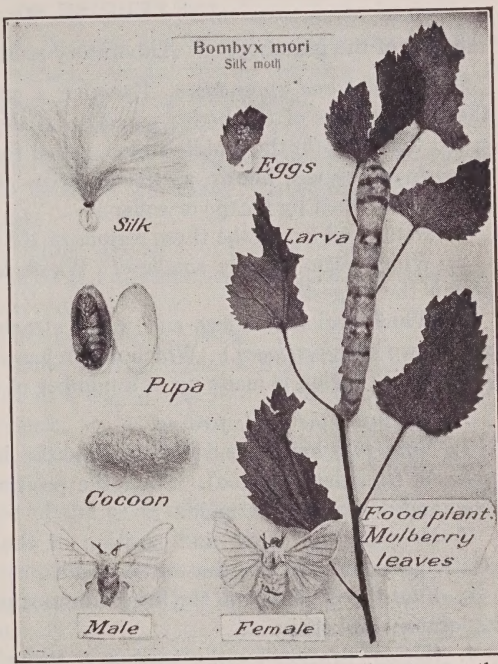


Fig. 238. — Life history of the silkworm moth

[1] Bailey's *Cyclopedia of American Agriculture*, III, 640.

II. Grasshoppers and Their Relatives

EXERCISE 60

Study of the grasshopper. Laboratory study.

A. Regions and appendages. Examine a grasshopper and distinguish the three regions of the body; namely, (*a*) the front, or *anterior*, region, called the *head;* (*b*) the middle region, called the *thorax;* and (*c*) the hind, or *posterior*, region, known as the *abdomen.* (The anterior region of the thorax is covered by a cape or collar.)

1. Name and locate the three regions of the body.
2. Which region is the smallest? Which is the widest? Which region is the longest?
3. Which region has legs and wings attached to it? (These organs are known as *appendages.*) Which region has other kinds of appendages?
4. Which region is made up of a number of similar rings, or *segments?*

B. Organs of the head; feeding.

1. Note two long, slender feelers on the head; they are known as *antennæ* (singular, *antenna*). State the position of the antennæ on the head and describe their shape.
2. Describe the shape and position of the large eyes. State their relative size compared to that of the head.
3. Find the *upper lip* on the lower anterior part of the head. Describe its location and shape.
4. (Demonstration by the teacher.) Raise the upper lip of a large grasshopper and find the *jaws*, or *mandibles*, beneath it. With a dissecting needle gently pry the jaws a little way apart. Do the jaws move from side to side or up and down?
5. Find the *lower lip* on the under side of the head (*i.e.* next to the thorax). It is divided vertically into two equal parts. Attached to either side is a tiny jointed structure called a *labial palp.*
   a. Describe the location of the lower lip.
   b. Describe the position and appearance of the labial palps.
6. (Demonstration or home work.) Place several grasshoppers in a cage or glass jar with moistened leaves of clover, grass, or lettuce. If these insects refuse to eat, try others till you find some that will eat.
   a. Describe the movements of the head and also the movements of the mouth parts while the grasshopper is eating.

b. Which mouth parts must do most of the biting of the leaf? Give the reason.

C. Organs of the thorax; locomotion.

1. How many legs has a grasshopper? Which pair is the largest?

2. Make a sketch (× 4) to show the following parts of one of the hind legs: (*a*) the large segment nearest to the thorax — the *thigh*, or *femur;* (*b*) the next segment to the femur — the *tibia;* (*c*) the part that rests on the ground when the insect walks — the *foot*, or *tarsus.* Use a magnifier to see the several segments in the tarsus, the little claws at the tip end, and a small pad between the claws. Label the femur, tibia, tarsus segments, claws, pads.

3. Get a grasshopper to climb up a stick or a piece of grass.

a. Tell what you have done and describe the movements of the animal that you have observed.

b. How is the insect able to cling to the stick?

4. (Demonstration or home work.) Place a lively grasshopper in a clear space on the floor or in a cage. Get it to jump enough times to determine the following points:

a. What is the position of the parts of the hind legs when the animal is ready to leap?

b. What is the position of the parts of the hind legs the instant the insect lands?

c. What does the grasshopper do to get ready for another jump?

d. What movement throws the insect into the air? Is this movement made slowly or quickly?

e. In what respects are the hind legs better fitted for jumping than are the other two pairs?

5. Move the outer wings of a preserved grasshopper sideways and forward at right angles to the body so as to expose the under pair. Spread out, or unfold, the under wings. (It is an advantage to mount the specimens on cork and pin the wings in the position named above.)

a. Which pair of wings is better fitted for flying? Give the reason.

b. How are the outer wings fitted to protect the under wings?

c. Draw (× 2) the outline of a front wing and of a hind wing and sketch in the veins. Label the front wing, hind wing, veins.

D. Organs of the abdomen; breathing.

1. (You will observe that each of the rings, or segments, of the abdomen is composed of an upper and an under part.) Make a sketch (× 4)

of a side view of four or five segments of the abdomen to show the structures mentioned above. Label the segment, upper part, lower part.

2. Secure an active grasshopper, put it in a live cage, and watch the movements of the upper and lower portions of the abdominal segments. Describe what you have observed.

3. In each segment, except those at the tip of the adbomen, there are two *breathing pores*, one on each side. With the aid of a magnifier look for these breathing pores near the lower margin of the upper part of each segment. When you have found the pores, show them in your sketch of the abdominal segments and label them.

261. Life history of the grasshopper. The male grasshopper may be easily distinguished by the rounded tip of the abdomen; the abdomen of the female has at its posterior extremity four movable parts which constitute the egg-laying organ, or *ovipositor* (Fig. 239). The eggs are produced within the body of the female insect. Before these eggs can develop, however, each must be fertilized by a sperm cell produced by the male grasshopper. After the process of fertilization has taken place, the female grasshopper (usually in the fall of the year) burrows a hole in the ground by alternately bringing together, pushing into the earth, and then spreading apart the four projections that make up the ovipositor. From 20 to 40 small banana-shaped eggs are then laid in the bottom of the hole. In the spring each egg hatches into a tiny grasshopper, which much resembles the adult, except that it has no wings and its head is relatively large in comparison with the rest of the animal. The insect begins at once to feed and grow; but since its whole exterior is hard and resistant, growth can only take place after this outer covering has

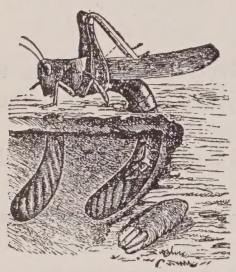


Fig. 239. — Female grasshopper

Note the egg masses below the surface of the ground.

been split and the insect has crawled out. The insect then forms a new and larger coat. This process is known as *molting* and takes place five or six times during the life history of the animal. At each molt the wings become more fully developed until at the last molt the adult insect is produced (Fig. 240). Hence in the life history of the grasshopper there are three more or less distinct stages: (1) the egg, (2) the developing insect, or *nymph*, and (3) the adult grasshopper. This succession of changes in a life history is known as *metamorphosis* (from the Greek, meaning *one form after another*).

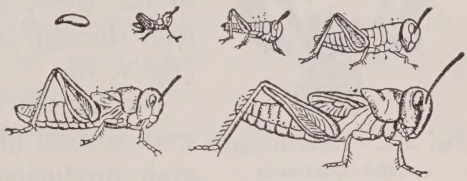


Fig. 240. — Life history of the grasshopper
Egg (upper left); five nymph stages.

But, because in the development of the grasshopper these changes are not so striking as those that occur in the life history of the butterfly (**253**), the metamorphosis of the grasshopper is said to be *incomplete*. It is better, however, to refer to it as a *direct metamorphosis*, that of the butterfly being known as an *indirect metamorphosis*. After reaching the adult stage and depositing eggs, the adult insects die. Only a few of the immature grasshoppers survive the winter, and these are the grasshoppers that are seen early in the spring.

262. Economic importance of grasshoppers. Our laboratory study of a grasshopper's mouth parts and our observations of its methods of feeding have shown that these insects resemble caterpillars, first, in having biting mouth parts (Fig. 241) and, second, in being voracious eaters. Hence, a large number of grasshoppers in a given area means a considerable destruction of plant life. Many "plagues of locusts" (for grasshoppers are more correctly

known as locusts) have been recorded in history. One of the first is that recorded in the *Bible*, which occurred before the departure, or "Exodus," of the children of Israel from Egypt. "And they [the locusts] did eat every herb of the land, and all the fruit of the trees . . . and there remained not any green thing in the trees, or in the herbs of the field through all the land of Egypt." (*Ex. x. 15.*)

Fig. 241. — Mouth parts of the cockroach

Upper lip, lower lip, jaws (center), helping jaws (at sides).

During the years 1866–1876 there were several plagues of locusts in the grain-producing states of the West, notably Kansas and Nebraska. The Rocky Mountain grasshoppers during these years migrated in such numbers that the sky was darkened during their flight, and the result of their devastation was as serious as that described in *Exodus*. According to one authority this species of insect destroyed $200,000,000 worth of crops in the Western States in four years. No great migrations have occurred since 1876.

Locusts have been used as food, and even at the present day they are commonly eaten by the Arabians. In the *Bible* it is related of John the Baptist that while preaching in the wilderness "he did eat of locusts and wild honey."

263. Relatives of the grasshopper. Other insects that have structure, habits, and life history similar to those of the grasshopper are the crickets, cockroaches, katydids, and walking sticks.

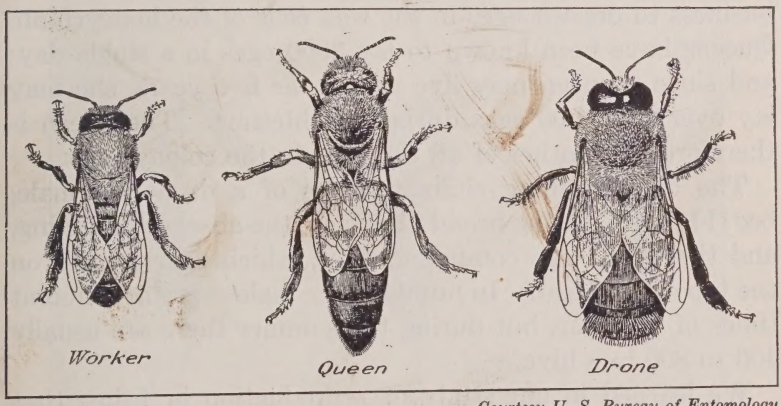
The cockroaches are more commonly known in New York City as "Croton bugs" from the fact that they frequent places close to water pipes through which Croton water is carried. They are very fast runners as anyone knows who has tried to catch them, and their bodies are so thin that they can easily hide away in narrow

cracks. Their sharp jaws enable them to feed upon dried bread and other hard food (Fig. 241).

Katydids and walking sticks are striking examples of *protective resemblance;* that is, they resemble their surroundings in form or color so closely that they may secure protection from their enemies by this means.

III. Bees and Their Relatives

264. What the characteristics of honeybees are. Honeybees and the less useful bumblebees are much alike in their general plan of structure; that is, in both kinds of insects the body consists of a head, thorax, and abdomen



Courtesy U. S. Bureau of Entomology

Fig. 242. — The three kinds of honeybees

all covered with hair (Fig. 242). The head of the honeybee is provided with organs similar to those of the bumblebee. There are two large eyes, two antennæ bent in the middle like a human arm at the elbow, and five slender mouth parts that make up the sucking organ. Likewise on the thorax are two pairs of membranous wings and three pairs of jointed legs.

In a colony of honeybees there are both male and female bees. But one female ordinarily is present, however, and she is known as the *queen*. The male bees are called *drones*. By far the greatest portion of a bee colony consists of a third kind of bee, known as the *workers*. The characteristic structures and the functions of each of these three kinds of bees will now be described.

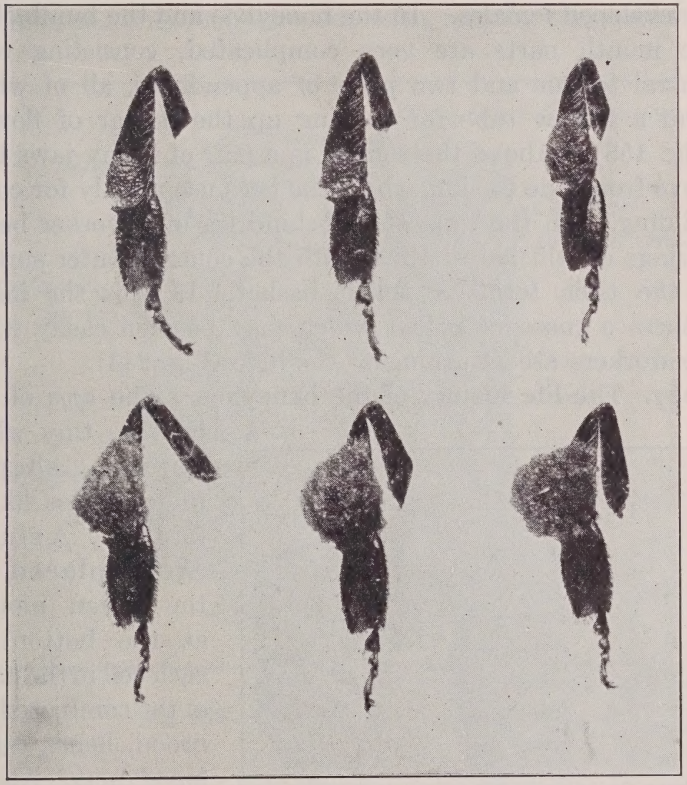
265. What the characteristics and the functions of the queen bee and of the drones are. In every colony of bees there is, except at intervals, only one queen. The queen (Fig. 242) can be distinguished readily from the other kinds of bees in the hive by her long, slender abdomen. It is her sole business to deposit eggs in the wax cells of the honeycomb. Queens have been known to lay 3000 eggs in a single day; and since a queen may live as long as five years, she may lay over 1,000,000 eggs during her lifetime. The queen is therefore the mother of all the bees in the colony.

The distinguishing characteristics of a drone, or male, bee (Fig. 242) are the broad abdomen, the absence of a sting, and the very large compound eyes, which nearly meet on the top of the head. In numbers the males vary at different times of the year, but during the summer there are usually 400 to 800 in a hive.

We learned in our study of reproduction in fishes that egg cells will not develop into embryos unless they are fertilized by the sperm cells of a male fish. Likewise in a beehive an egg will never develop into a queen bee or a worker unless it is fertilized by a sperm cell. The drones furnish these necessary sperm cells. From the unfertilized eggs, which a queen may also lay, only drone bees are produced. In this respect the egg cells of bees are strikingly different from those of plants and of most animals.

It is clear, therefore, that the queen and drones carry

on the *reproductive functions* of the colony, for they are especially adapted to increase the number of bees in a



Courtesy U. S. Bureau of Entomology

Fig. 243. — Pollen basket of the honeybee

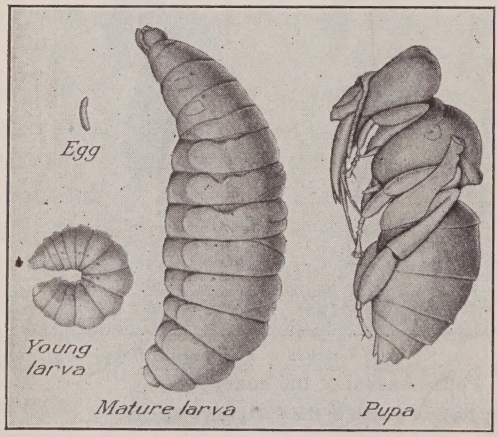
Note the increasing load of pollen in the successive figures.

hive. To the workers, however, belong most of the *nutritive functions* of the colony as we shall now see.

266. What the characteristics of worker bees are. While the workers are smaller than either the queen or the drones,

they are by far the most numerous, there being as many as 50,000 in a good colony in midsummer. In shape they resemble the queen, as one would expect, since they are undeveloped females. In the honeybee and the bumblebee, the mouth parts are very complicated, consisting of a central tongue and two pairs of appendages, all of which form a hollow tube for sucking up the nectar of flowers (Fig. 158). Above the tongue is a pair of horny jaws that move from side to side, which the bees use mainly for comb building. On the tibia of each hind leg of a worker bee is a fringe of stiff hairs, which with the concave outer surface of the tibia forms a pollen basket. In this the insect gathers a mass of pollen which may be seen easily when the workers are returning to the hive (Fig. 243).

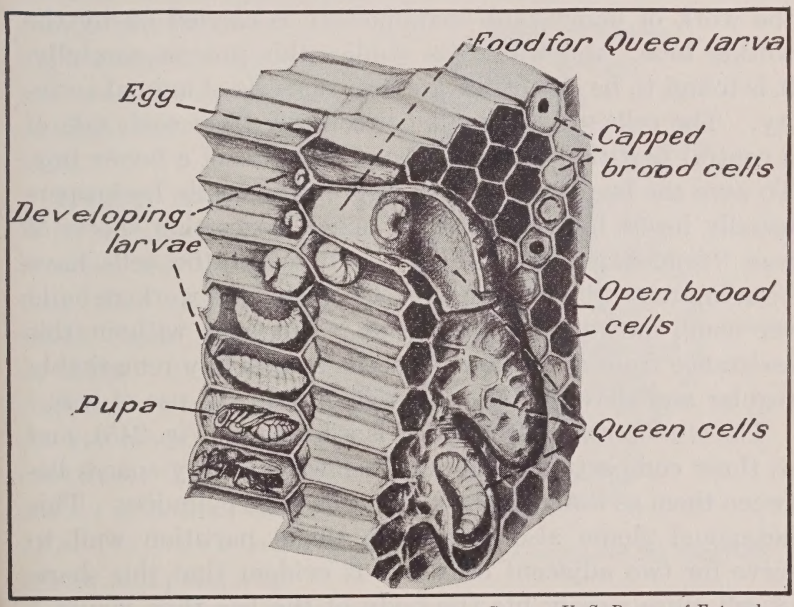
267. The life history of the honeybee. The *eggs* of the bee are tiny white objects, shaped more or less like a banana. A single egg is placed by the queen mother at the bottom of each cell in the parts of the comb used for brood, hence called *brood comb*. At the end of three days the egg hatches into a minute footless *grub*, or *larva* (Fig. 244). This is fed for the first few days on rich food produced in the stomachs of the workers which are acting as nurses. The grubs are



Courtesy U. S. Bureau of Entomology

Fig. 244. — Life history of the honeybee

then fed with a mixture of pollen and honey, and at the end of six days after hatching they are supplied with enough of this mixture to last during the rest of the larval stage. The cells are then capped over with wax by the workers.



Courtesy U. S. Bureau of Entomology

Fig. 245. — Development of the honeybee

There the developing bees pass through the third, or *pupa*, stage (Fig. 245). At the end of twelve days they bite their way out of their nursery cells and take their share in the busy toil of the hive.

Drones develop in somewhat larger cells than worker bees and come from unfertilized eggs. When the colony wishes to produce a queen, the workers construct a cell about as large as the end joint of one's little finger (Fig. 245);

and as soon as the egg is hatched, they stuff the little grub throughout the larval period with "royal jelly," never giving it the undigested pollen mixture that is supplied to the grubs of workers and drones.

268. The duties of worker bees. *Comb building.* All the work of honeycomb manufacture is carried on by the worker bees; and when one studies this process carefully, it is found to be one of the greatest marvels of animal activity. The cells are built out horizontally from each side of a central partition wall of a brood frame or of a honey box. To save the bees' time and to insure even comb, beekeepers usually insert in the frames or honey boxes thin sheets of wax "foundation" on which the bases of the cells have been impressed by machinery. Upon this the workers build the comb outward on either side. But even without this assistance from man the comb cells are usually remarkably regular and show the greatest economy in the use of wax.

The cross section of each cell is a hexagon (Fig. 245), and so these compartments fit together without any spaces between them as would occur if the cells were cylinders. This hexagonal shape also permits a single partition wall to serve for two adjacent cells. It is evident that this shape of cell more closely fits the body of the bee than would a four-sided cell. The worker bees build two different sizes of cells in the comb. Most of the cells average about twenty-five to a square inch. In these the honey is stored, or the fertilized eggs which develop into workers are laid. The cells in which the unfertilized eggs are deposited are somewhat larger. These form the drone comb.

The wax from which the comb is produced oozes out from certain glands on the under surface of the abdomen of the workers. When producing the wax, the bees hang motionless inside the hive for several days, each holding to the

bees above. They have already gorged themselves with honey, and it is estimated that from seven to fifteen pounds of honey are required to produce one pound of wax. As the little plates of wax are formed, they are seized by a bee and carried with its mandibles or under its "chin" to the comb where the building is going on. Here the wax is pressed against one of the walls.

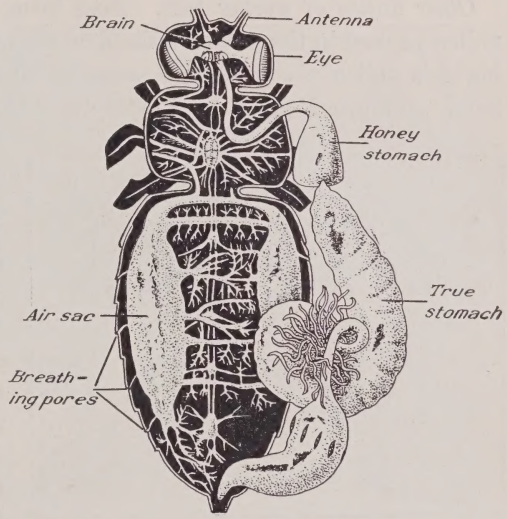


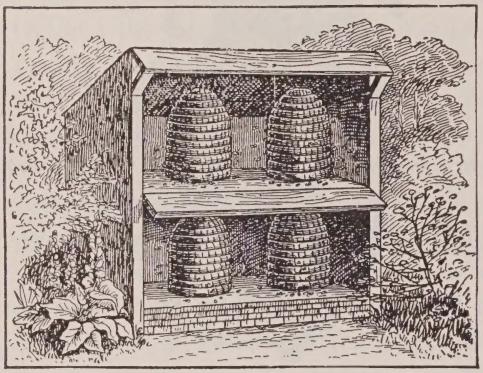
Fig. 246. — Internal organs of the honeybee

Honey making. While studying flowers, we learned that they secrete a sweet liquid known as *nectar*. It is this that the worker bees use for honey manufacture. The bee inserts into the blossom its sucking tongue and pumps up the nectar into a sac known as the *honey stomach* (Fig. 246). Here a kind of digestion takes place whereby the nectar is changed to honey. If the worker bee is hungry, it opens a little trapdoor and allows the honey and pollen to pass into the true stomach.

But since the insect usually makes more honey than it can use, on its return to the hive it squeezes its tiny honey stomach and deposits the surplus in the cells of the comb. The honey, when first made, contains a good deal of water; it would, therefore, take up too much room in the comb, and it would be more likely to run out from the horizontal

cells. Hence some of the worker bees vibrate their wings so rapidly inside the hive that they can not be seen and thus evaporate the surplus of water. When the cells are completely filled, they are capped over with wax.

Other duties of worker bees. Bees bring in large quantities of pollen packed in the pollen baskets on the hind legs, and in gathering this pollen a considerable amount clings to the hairs on the head and other parts of the body. This pollen when mixed with honey forms the *beebread* eaten by the young.



Courtesy Dodd, Mead and Company

Fig. 247. — Old type of beehive

Worker bees also bring in from the buds of trees a brown gummy substance called *bee glue,* which they use to close up crevices in the inside of the hive. In most hives too certain worker bees seem to be detailed to act as soldiers to keep out individuals from another swarm or other marauders that might raid their stores of food. During the busy summer season a worker usually lives only a month or two.

Certainly enough has been said to convince anyone that a bee colony is a wonderful social community, organized more completely, so far as division of labor is concerned, than many a human community. Is it a monarchy ruled by the queen or a democracy controlled by the workers? The latter is more probably the case. Yet we can hardly imagine how the thousands of individuals can work together in such a helter-skelter fashion and accomplish such wonderful results.

269. In what ways bees are of importance to man. In our study of flowers, we referred frequently to the necessity of the visits of bees to insure cross-pollination. Indeed Professor Hodge says that, for all practical purposes so far as man is concerned, the honeybee is sufficient for this

Courtesy U. S. Bureau of Entomology

Fig. 248. — Modern type of beehive

Observe the entrance at the lower part of each. The lowest box is the brood chamber; the upper (super) boxes contain the honey.

function, except in the case of the red clover which requires the help of the bumblebee in the pollination of the flower. In years to come we may be sure that the most successful farmers and fruit growers will make a practice of keeping bees.

It is estimated that the annual production of honey and wax in the United States amounts to between twenty and

thirty millions of dollars. If scientific management were to be introduced more widely, this output could be raised to fifty million dollars a year without additional investment.

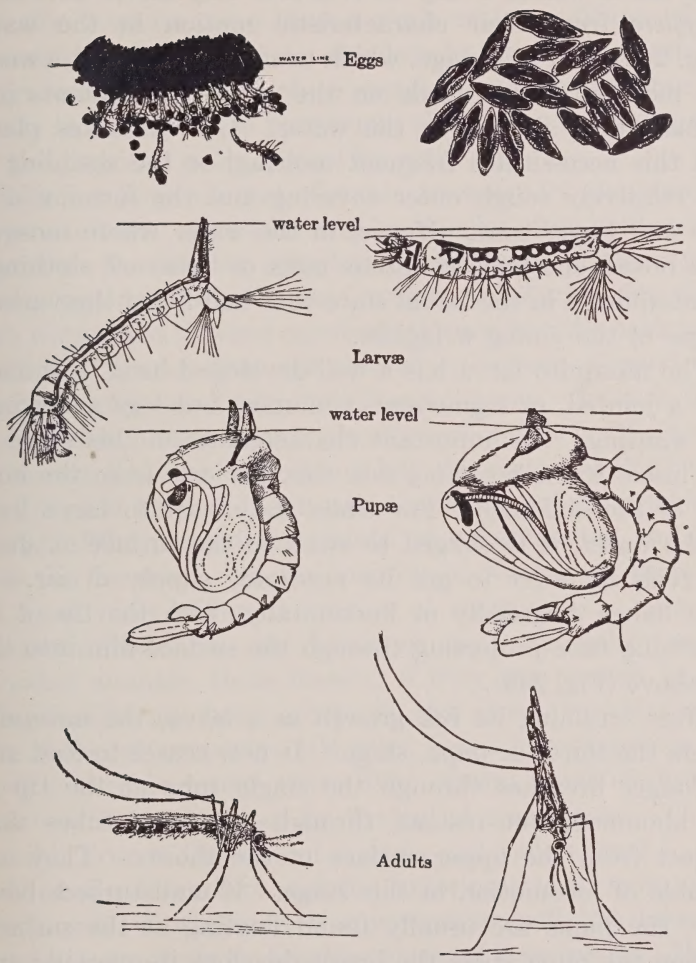
270. The swarming of bees. We now come to one of the most interesting events in the story of bee colonies. If several queens emerge from their cells at the same time, they attack each other in a battle royal, for it is said that a queen bee never uses her sting except against a rival. When the conflict is over, the victorious queen becomes the mother of the hive, for in the meantime the former queen, surrounded by half of the workers and drones, has left the old hive, abdicating in her daughter's favor.

After emerging from their old home, the swarm of bees thus formed alights on a neighboring tree, clinging to each other in a large solid mass. It is then comparatively easy for a bee-keeper to shake the insects from the limb into a new hive. If the queen is secured, the swarm will usually begin work at once in its new home. If, however, the bees are not captured, scouts go out to search for a hollow tree. When satisfactory quarters are found, the whole swarm follows its guides and builds its comb in the home thus secured.

271. Some of the relatives of the bees. Wasps and hornets belong to the same order of insects as the bees and resemble them more or less in structure. Some kinds of wasps build paper comb from wood that they chew with their jaws. Ants — insects with which everyone is familiar — are likewise classed with the bees and wasps, and the social communities that they form are marvelous in the degree to which they carry division of labor. In some ant colonies, in addition to the workers, there are soldiers and slaves.

IV. Mosquitoes and Flies

272. The characteristics and the life history of mosquitoes. Unlike the insects we have studied thus far, mosquitoes lay their eggs in water that is quiet or stagnant. If the weather is warm and if other conditions are favorable, the



Courtesy U. S. Bureau of Entomology

Fig. 249. — Life history of the mosquito

At left, house mosquito; at right, malaria mosquito.

eggs hatch within a day or two into tiny larvæ known as *wrigglers* from their characteristic motion in the water (Fig. 249). In this stage, which usually lasts about a week, the mosquito larva feeds on the microscopic plants and animals that abound in the water. Growth takes place, and this necessitates frequent molting, or the shedding of the relatively tough outer covering and the forming of a new and larger coat. Hence, in the water where mosquitoes breed, one finds countless suits of "cast-off clothing" of mosquitoes in the larval state that had fitted the various stages of the young wrigglers.

The mosquito larva has a well-developed head, a thorax, and a jointed, or segmented, abdomen, but legs and wings are wanting. An important characteristic of this stage of the insect is the *breathing tube* that projects from the hind end of the abdomen. For while the mosquito larva lives in the water, it is obliged to swim to the surface at short intervals in order to get its necessary supply of air. It then hangs diagonally or horizontally, with the tip of its breathing tube projecting through the surface film into the air above (Fig. 249).

After attaining its full growth as a larva, the mosquito enters the third, or *pupa*, stage. It now ceases to feed and no longer breathes through the single tube at the tip of the abdomen, but instead through a pair of tubes that project from the upper surface of the thorax. They are capable of locomotion in this stage. If undisturbed, however, the pupæ are usually found floating at the surface. During the pupa stage the insect develops its piercing and sucking mouth parts, its long and slender legs, and its gauze wings.

At the final molt the mosquito leaves its pupal case in the water and flies into the air an *adult* mosquito. If it is

hatched during the spring, summer, or early autumn, it usually lives no more than a week or two. Many of the females, however, that develop late in the autumn seek out a protected spot in which to spend the winter and thus are ready in the spring to perpetuate the species by laying eggs in the stagnant pools formed by early rains.

Nor is a large amount of water necessary for the breeding of mosquitoes. The following receptacles often hold enough water to provide for complete development of these pests from eggs to adults, if they remain undisturbed for about two weeks: old tin cans carelessly thrown into the back yard; gutters of houses that are allowed to remain clogged with leaves; unscreened rain barrels and cisterns. In such cases the careless householder is directly responsible for the hordes of insects that not only annoy but also endanger the health and lives of his own family and the families of his neighbors.

273. Why mosquitoes should be exterminated and how this can be done. In the vicinity of New York there are at least forty different species of mosquitoes. Since all of them feed upon the blood of man and other warm-blooded animals, these insects, if they are present in any considerable numbers, are pests and cause depreciation in the value of property. Of even more importance is the fact, proved in recent years, that certain kinds of diseases can only be transmitted by the aid of mosquitoes. This is notably true in the case of malaria and yellow fever.

Now the discomfort and the suffering due to mosquitoes are largely unnecessary, if communities will but take the trouble *to eradicate the breeding places of these insects*. Every householder should make sure that he is not allowing mosquitoes to breed near his home. He should clean up his own back yard and cover cisterns and open wells with the finest-meshed netting.

Fish, especially goldfish and minnows, and dragon flies are also important helps to man since these animals devour great numbers of larvæ, pupæ, and adult mosquitoes. In fact in some communities in the United States a fish known

Courtesy N. Y. Board of Health

Fig. 250. — Breeding place of mosquitoes
Note the ditching machine at the right.

as the top minnow has been the main agency in the control of mosquito pests in ponds, pools, and streams near farmhouses. In many South American communities also, where the supply of water for household use is kept in rain barrels, the minnow has been of great service in destroying mosquito eggs, larvæ, and pupæ.

Since the mosquito, during its development in the water, comes frequently to the surface to secure air for breathing, a *thin film of oil* spread over the surface of the water of

Courtesy N. Y. Board of Health

Fig. 251. — Draining swamp land

What is the advantage of the clean-cut, vertical sides of the ditches?

swamps and pools in which they are breeding is a sure means of killing them. But the oil treatment is at best but a temporary means of ridding the community of mosquitoes, since the oil has to be renewed every two or three weeks, especially after rains, to make sure that a continuous film covers the surface.

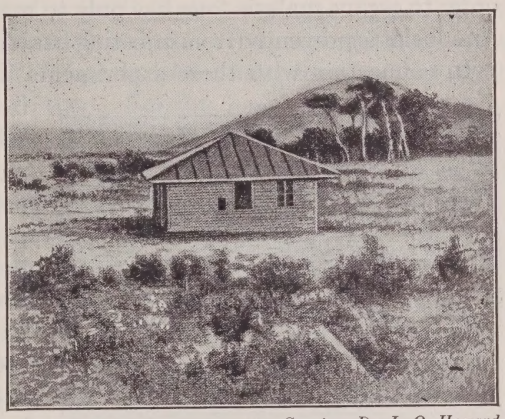
Wherever possible, therefore, pools and swamps should be *filled in*. If this is impossible on account of expense as in the case of the salt marshes, *ditches with vertical sides* should be dug that will connect with open water (Fig. 251). In this way water will move into the ditches with the high tide, and out with the low tide. In the case of fresh-water swamps and marshes the ditches should connect with running water, such as creeks and rivers. By these methods of ditching the water is kept in motion, and so mosquito eggs, larvæ, and pupæ are carried away before they have time to complete their development.

274. How it was proved that the female Anopheles transmits the germs of malaria. Until comparatively recent times malaria was supposed by many people to be due to some *ague* or *miasma* that came from foul air, especially the air found in swampy regions — hence the name *malaria* (from the two French words, meaning *bad air*). It is true that some of the older writers spoke of the presence of insects during the malaria season. But only here and there was the suggestion made that insects might in any way be responsible for the spread of the disease.

One of the most wonderful stories of biological discovery is that which recounts the steps by which malaria was proved never to occur except as a result of the bite *of a certain kind of mosquito* — namely, the *female Anopheles* (Fig. 249). The first step in this proof was taken in 1880 when Major Laveran, a French military surgeon on duty in northern Africa, found that a certain microscopic parasite was always present in the blood of malaria patients. In 1898 Major Sir Ronald Ross, an English medical officer in India, proved the presence of a similar parasite in the body of the female Anopheles.

It was now necessary to determine how this parasite is transmitted from man to a mosquito and then from a mosquito to man. A long series of investigation showed that, when the female Anopheles bites a malaria patient, she swallows with the blood she

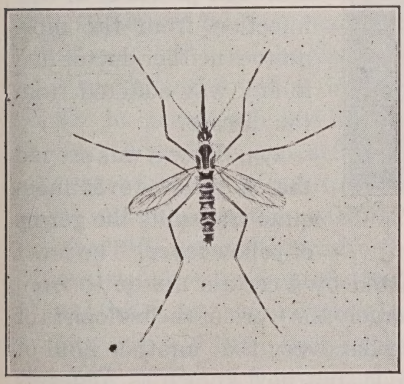
secures some of the parasites such as Laveran had discovered. After a time some of these parasites escape through the wall of the mosquito's stomach and reach her salivary glands. Hence, when she comes to bite a new victim, she injects with her saliva some of the parasites, which, if conditions are favorable, cause the malarial chills and fever in the individual bitten.



Courtesy Dr. L. O. Howard

Fig. 252. — House used in experimental tests with Anopheles mosquitoes

That the germs of this disease can be transmitted only by the female Anopheles and in the way we have described was proved beyond a doubt by many experiments conducted by two scientists who spent the fever season in the dreaded malarial district of the Roman Campagna. They built for themselves a carefully screened house in which they remained from sunset to sunrise, since the malaria mosquito bites only at night (Fig. 252). In the daytime, however, they went freely among those who were stricken with the fever, they allowed themselves to be soaked with the falling rains, and at night they permitted the air from the swamps to come freely into their screened sleeping



Courtesy U. S. Bureau of Entomology

Fig. 253. — The yellow-fever mosquito

quarters. But while hundreds of malaria cases were all about them, not one of the men contracted the disease. Hence, in order to escape malaria, one has only to make sure that the female Anopheles is prevented from injecting her bill with its malaria germs.

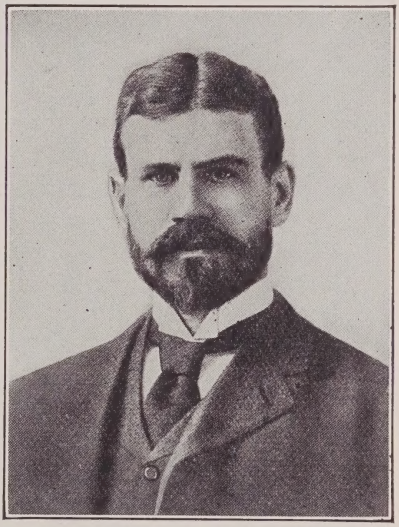
In connection with these experiments in Italy, two physicians in London allowed themselves to be bitten by mosquitoes which had previously bitten malaria patients in Italy and had been sent in a small wooden box to London. In eighteen days after these infected mosquitoes had bitten these doctors, both of them developed malarial fever, and in the blood of both malarial organisms were found although previous to this infection from the mosquitoes neither doctor had in any way suffered from the disease.

From Kelly's Walter Reed and Yellow Fever

Fig. 254. — Dr. Walter Reed

275. How it was proved that a yellow-fever mosquito transmits the germs of yellow fever. The proof that malaria can only be transmitted by a certain mosquito from one human being to another was largely the work of the biologists of England, France, and Italy. The discovery that another kind of mosquito (formerly called Stegomyia, but now known as Aëdes) is responsible for the transmission of the parasite that causes yellow fever, however, is due to the splendid achievements of the Yellow Fever Commission appointed by President McKinley. In June, 1900, the Commission of five, headed by Dr. Walter Reed, who was

the inspiring genius of the Commission, began its epoch-making experiments in the island of Cuba. Within six months these men had demonstrated beyond a doubt that this plague disease of the tropics and of our Southern States could be communicated only through the agency of the female Aëdes that had been infected with the germs of yellow fever. For this reason these mosquitoes are known as yellow-fever mosquitoes.



From Kelly's Walter Reed and Yellow Fever

Fig. 255. — Dr. Jesse Lazear

This Commission, impressed by the mosquito theory first suggested by Carlos Finlay of Havana, at once began experiments to demonstrate its truth. One of the members, Dr. Jesse Lazear (Fig. 255), permitted a mosquito to bite him. A few days later he contracted the dread disease and from it he died. The inscription on a tablet erected to his memory in a Baltimore hospital reads as follows: "With more than the courage and devotion of a soldier he risked and lost his life to show how a fearful pestilence is communicated and how its ravages may be prevented."

Dr. Carroll, another member of the Commission, was also stricken with yellow fever after having been bitten by a mosquito. These two cases were convincing to Dr. Reed, but they could not be published as positive proof to the scientific world because in neither case had there been experimental control. Hence, further experimentation was necessary. When it became known among the troops that subjects were needed for experimental purposes, the first to respond was John R. Kissinger. He in company with another young private, John J. Moran, also from Ohio, volunteered for this service. This they did, in the words of Kis-

singer, "solely in the interest of humanity and in the cause of science." Dr. Reed talked the matter over with them, explaining fully the danger and the suffering involved in the experiments should they be successful. Then, seeing that they were determined, he stated that a definite money compensation would be made them. Both young men declined to accept it, making, indeed, their sole stipulation that they should receive no pecuniary reward. Whereupon Major Reed touched his cap, saying respectfully, "Gentlemen, I salute you." Kissinger, having been bitten by mosquitoes infected with yellow-fever germs, was the first to get yellow fever under experimental conditions. "In my opinion," says Dr. Reed, "this exhibition of moral courage has never been surpassed in the annals of the Army of the United States."

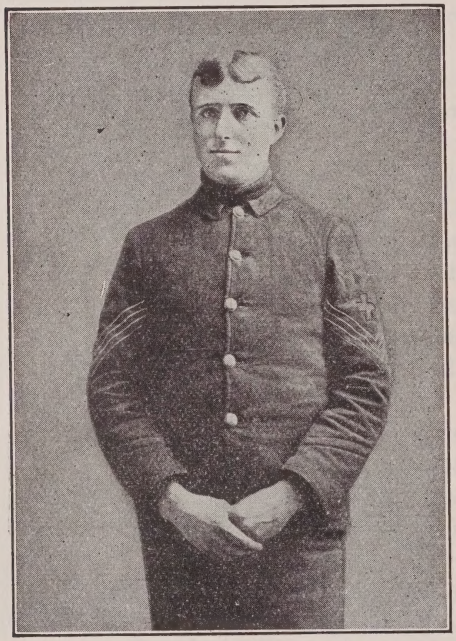
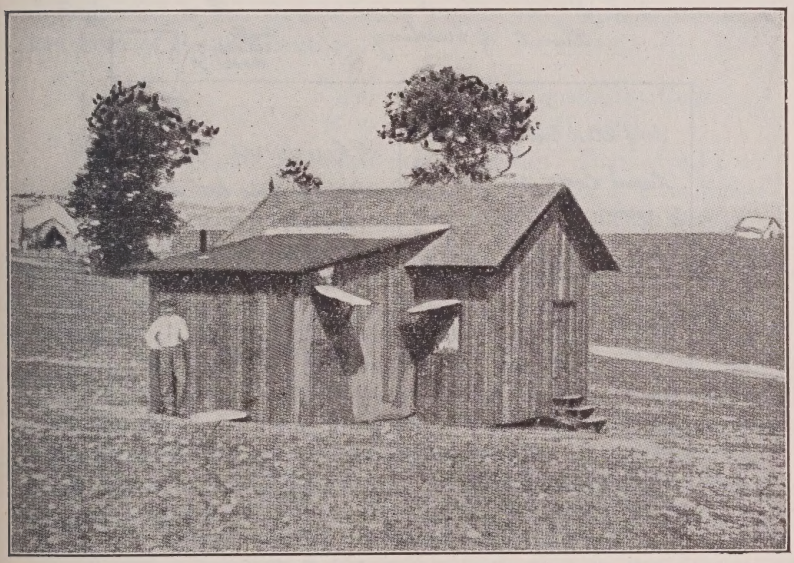


Fig. 256. — John R. Kissinger

The object of one of the first experiments was to determine whether or not yellow fever could be contracted from clothing worn by yellow-fever patients. A small building was constructed, the windows and doors being carefully screened. Into this were brought chests of clothing that had been taken from the beds of patients some of whom had died of yellow fever. Three brave men, Dr. Robert P. Cooke and two privates of the hospital corps named Folk and Jernigan, entered the building, unpacked the boxes, and for twenty nights stayed in close contact with the soiled

clothing. "To pass twenty nights in a small ill-ventilated room, with a temperature over ninety, in close contact with the most loathsome articles of dress and furniture, in an atmosphere fetid with their presence, is an act of heroism which ought to command our highest admiration and our lasting gratitude." [1] In spite, however, of these unwholesome surroundings, none of the men



From Kelly's Walter Reed and Yellow Fever

Fig. 257. — House in which the tests were made with infected clothing

contracted yellow fever. And so it was proved for all time that this disease can not be communicated by means of anything that comes from the bodies of yellow-fever patients.

Dr. Reed now set out to prove that the female Aëdes was the mosquito by which the disease was transmitted from one person to another. A second building of the same size as the first was erected. The room was divided by a wire screen, and all the doors and windows were screened carefully (Fig. 258). Into one of the

[1] From *Walter Reed and Yellow Fever.*

rooms a number of mosquitoes that had bitten yellow-fever patients were freed, and a few minutes later John Moran entered and allowed these mosquitoes to bite him fifteen times. On Christmas morning, 1900, at 11 A.M. this brave man was stricken with yellow fever, but he bore the sharp attack without a murmur.

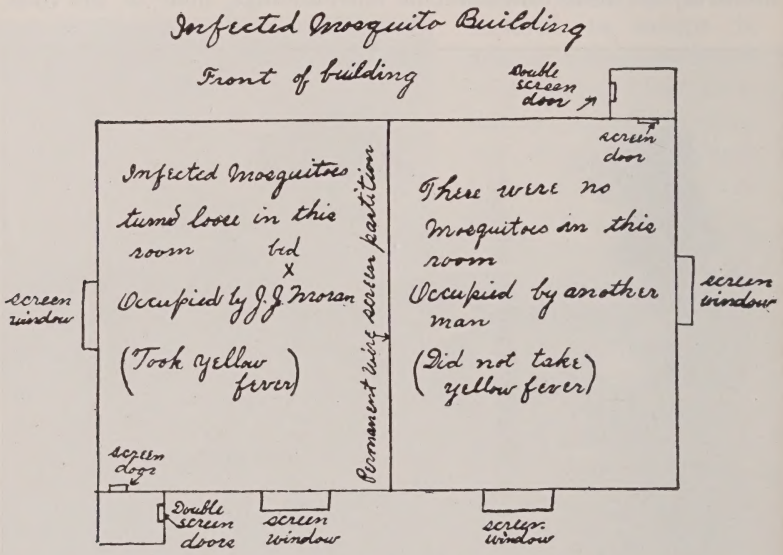


Fig. 258. — Plan of infected mosquito house
Drawn for the authors by John R. Kissinger.

On the other side of the screen were three soldiers who were protected from mosquitoes; and these men remained in perfect health. This experiment proved beyond a doubt that yellow fever is transmitted by this particular mosquito. Fortunately none of the other doctors or the soldiers who were stricken were called upon, as was Dr. Lazear, to give up their lives in Cuba. Many of those who were experimented upon, however, paid the price of early death or long sickness after the experiments were over.

The order with the significance of the crucial experiments tried

in Cuba was this: Kissinger's case established once and for all that yellow fever is conveyed by the bite of a mosquito. Moran's case proved that the mosquito in question is Aëdes (formerly known as Stegomyia). The experiment of Dr. Cooke and others with the infected clothing demonstrated that yellow fever is *not* conveyed, as was formerly believed, by emanations that come from the bodies of yellow-fever patients.

Following is Dr. Reed's letter to his wife, written during the last hour of the last century:

> Columbia Barracks, Quemados, Cuba
> 11:50 P.M., December 31, 1900.
>
> Only ten minutes of the old century remain. Here have I been sitting, reading that most wonderful book, *La Roche on Yellow Fever*, written in 1853. Forty-seven years later it has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and to put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old century. May its cure be wrought out in the early days of the new! The prayer that has been mine for twenty years, that I might be permitted in some way or at some time to do something to alleviate human suffering, has been granted! A thousand Happy New Years. . . . Hark, there go the twenty-four buglers in concert, all sounding "Taps" for the old year.

276. What has been found out in regard to the cause and prevention of yellow fever. It was not until the year 1918, that is, eighteen years after the transmission of yellow fever by mosquitoes was demonstrated, that a Japanese scientist at the Rockefeller Institute, Dr. Noguchi, discovered the cause of this terrible scourge to be a single-celled parasite (Figs. 259, 260). In 1919 Dr. Noguchi prepared a vaccine to prevent yellow fever. This vaccine is similar to typhoid vaccine since it is prepared from the dead germs of the disease to be prevented. This yellow-fever vaccine has been used on human subjects in large numbers of cases and with gratifying success. As an example, the following

account may be given: In one community in Peru, South America, 200 non-immune soldiers were vaccinated, and in another district of Peru 200 non-immune civilians also were vaccinated. Both soldiers and civilians passed through a severe epidemic of yellow fever without a single one of them contracting the disease.[1]

Courtesy Dr. H. Noguchi

Fig. 259. — Yellow-fever germs

Photographed alive through ultramicroscope; magnified 3000 times.

Courtesy Dr. H. Noguchi

Fig. 260. — Yellow-fever germs

Germs dead and stained in liver tissue; magnified 1000 times.

277. What the habits and life history of the house fly are. Scientists have proved that the common house fly is undoubtedly the carrier of disease germs. Especially is this true in the transmission of typhoid fever and the intestinal diseases to which the deaths of so many young children are due. Practically all parts of the body of the fly are covered with hairs, and this is especially true of the mouth parts and of the feet. Each foot also has sticky

[1] See *Eighth Annual Report of the International Health Board of the Rockefeller Institute*, 1921, p. 13.

pads (Fig. 261), which enable the fly to cling to the walls and ceilings.

In the adult stage the flies feed upon filth of all sorts; and if they alight on the excretions from the intestines and kidneys of typhoid patients, they are almost sure to carry on their feet and mouth parts the germs of the disease; then when they come into the house, flies may infect milk and other foods. Flies also carry germs of other diseases such as cholera, dysentery, and tuberculosis.

Fig. 261. — Fly's foot

The most common breeding places of house flies are in piles of horse manure, garbage, and other decaying material. Here the female fly lays about 120 eggs (Fig. 262), which hatch within a few hours into tiny white, legless grubs. These feed for about five days upon the manure or other filth and grow rapidly, molting twice within that time. The larva now changes into a pupa, and at the end of another five days the adult fly emerges from the brown pupa case. Egg laying begins almost at once, and, since each adult female lays about 120 eggs, it has been estimated that a single fly through the several generations of a single season might have 5,598,720,000 descendants if each fly were to deposit but one batch of eggs and all the descendants were to survive. In reality, however, a fly usually lays four batches in a season! Hence it is very important to catch and kill flies at the very beginning of each season.

278. How house flies may be exterminated. Because of the danger of disease transmission and because flies are filthy in their habits, every housekeeper should keep food covered, kill the few flies that may remain, and so keep flies away from the food, for one never knows where they have been crawling or what disease germs may be clinging

to their feet. Fly traps and sticky fly paper will catch most of the flies that find their way into homes.

City authorities should see that all street refuse and garbage are removed before flies of any kind can lay their eggs therein. All persons responsible for horse stables

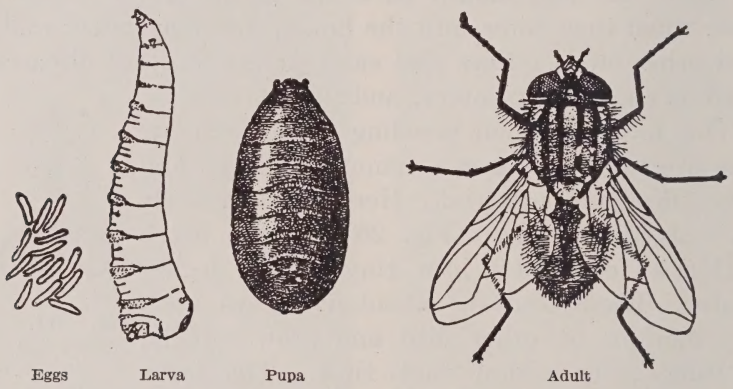
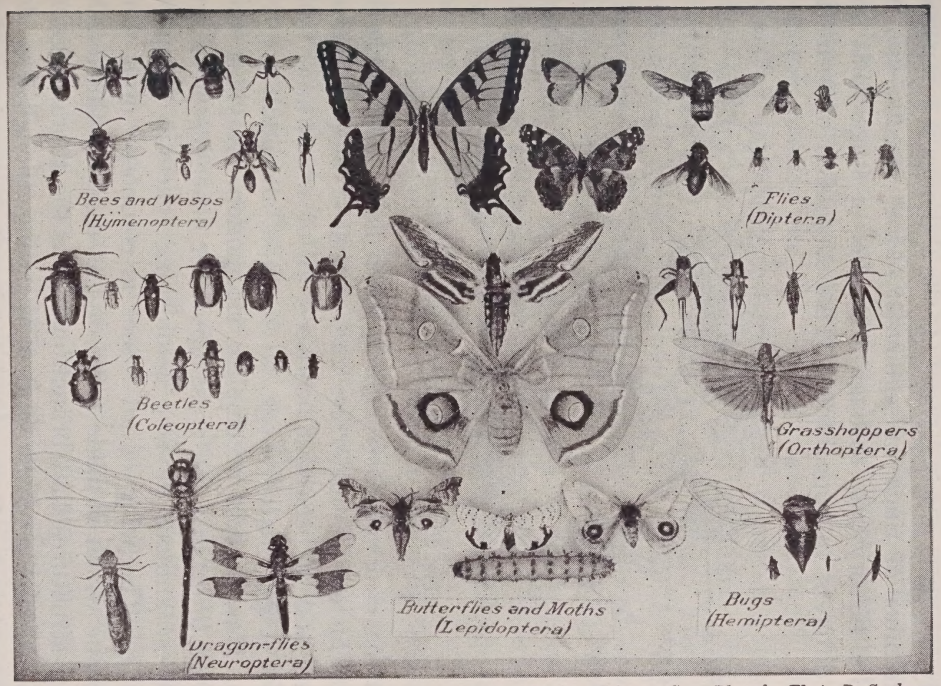


Fig. 262. — Life history of the house fly

should make sure that the manure either is removed each day or else is packed into tightly covered receptacles and then removed at least twice a week. To make sure that house flies do not breed in the manure, it should be treated with borax or chloride of lime. If these various suggestions are followed, even farmhouses may be rendered practically free from the filthy and dangerous house fly.

V. Comparison of Insects

279. What the characteristics of insects are. If one were to make a collection of insects, something like that shown in Fig. 263, one would find that all these animals resemble each other in the following respects: (1) Their bodies are divided into three distinct regions, head, thorax,



Prepared by Kny-Scheerer Co. Photo by Elwin R. Sanborn

Fig. 263. — Insect collection

and abdomen; (2) the head bears two antennæ and a pair of large eyes; (3) the thorax bears three pairs of legs and usually two pairs of wings; and (4) the abdomen is composed of a number of rings, or segments. Most insects, too, in their life history pass through a number of stages that are quite different in appearance. This succession of forms is

Fig. 264. — Life history of the potato beetle

known as *metamorphosis* and is particularly noticeable in the life history of butterflies and moths, of flies and mosquitoes, and of bees and beetles — all of which have four distinct stages; namely, egg, larva, pupa, and adult.

280. How insects accomplish locomotion. Anyone who has tried to catch a fly, grasshopper, or other insect knows that these animals develop astonishing speed in flying or jumping. The wing of an insect is composed of a thin membrane which is made more or less rigid by thickened, tubular structures that branch out from the thorax region. These are known as the *veins* of the wing, though they do not carry blood. If we watch an insect (*e.g.* a butterfly) when it is flying, we note downward and upward movements of the wings. Since the weight of the animal and the

upward stroke of the wings against the air would tend to drive the animal downward, it is evident that, in order to keep at a given level or to rise in the air, more force must be used in the downward than in the upward stroke. If the insect is to move forward, the wings must not only strike downward but also backward.

Some insects, like the butterfly and the moth, have a relatively large expanse of wings, and therefore a relatively slow wing movement only is necessary in flight. Bees and flies, however, have comparatively small wings. These wings are moved so fast that they become invisible. Since in these wing movements a musical note is produced, scientists have been able to compute the rate of vibration by comparing the sound produced with that on the musical scale. By the use of tuning forks it has been found that in male mosquitoes this rate of wing vibration is as high as 880 per second; in the female it is 480 per second.[1]

All insects can move from place to place by using their three pairs of legs in walking, crawling, or jumping. In many cases the feet are provided with hooks or pads (Fig. 261), which enable the animal to cling to its support, or in some cases (*e.g.* the house fly) to climb a smooth surface that is vertical or even to walk upside down.

Grasshoppers in addition to their wings are provided with other and most effective organs of locomotion. In fact they derive their name from the extraordinary feats of jumping which they accomplish largely by their long and muscular hind legs. If a boy could jump twenty times the length of his legs, that is, a distance of fifty feet from a standing position, he would make an athletic record corresponding to that of the common red-legged locust. For the hind legs of an ordinary specimen of this insect are

[1] *Mosquitoes of North America*, p. 116.

about two inches long and they frequently leap four feet. A flea, in proportion to its size, can jump even farther.

281. How insects breathe. Insects also resemble each other in another respect. If we watch a grasshopper or a bee, we may observe that the abdomen alternately expands and contracts; and because of the similarity of these movements to those that take place in our own chest region, we are quite right in concluding that these movements have to do with breathing. Now why must an insect breathe? In carrying on locomotion it is evident that considerable energy must be liberated and used. So far as we know, this, like other body activities, is possible only as a result of the process of oxidation. Hence, the insect must be liberally supplied with oxygen; and as a result of this process of oxidation, the carbon dioxid produced must be given off from the body.

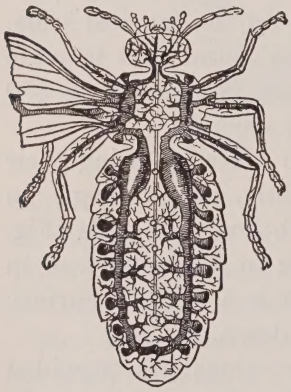


Fig. 265. — Air tubes of an insect

In our own bodies air is taken in through the nostrils and carried to the lungs, and the waste carbon dioxid is given off through the same passages. In an insect the openings for this purpose are not found on the head as in our bodies but along the sides of the body, a pair of breathing pores (*spiracles*) occurring one on either side of most of the segments of the thorax and abdomen. Each breathing pore leads into a tiny tube, which connects with the tubes from other pores, and these breathing tubes extend to all parts of the body and even out into the veins of the wings. In this way all parts of the insect are supplied with oxygen, and from all parts of the body carbon dioxid is removed. Hence, as in the human body, oxygen and carbon dioxid are carried in a definite system of tubes, but, unlike in the human body, these tubes carry gases only and not blood (Fig. 265).

Each segment of the abdomen of an insect consists of an upper portion and a lower portion connected by a flexible membrane. When the lower part of each segment is moved upwards, the size of the body is decreased and so pressure is exerted on the air tubes. In consequence air with its waste carbon dioxid is forced out through the breathing pores.

Like the air tubes in our own lungs the breathing tubes are composed of elastic material. The tubes therefore resume their former size after pressure is removed. Hence, when the under side of the abdominal segments is moved downward, the elastic tubes enlarge, air rushes into the breathing pores, and so oxygen is supplied to all parts of the body.

282. How insects eat. In general, insects may be divided into two groups: those that eat solid food and those that suck up liquid food. One of the marked characteristics of butterflies and moths is the long sucking tube. Through this hollow structure these insects draw up the nectar or other liquid on which they feed. When the sucking tube is not in use, it is rolled into a tight coil beneath the head and so is out of the way when these insects move from place to place. Bees also secure nectar by a sucking tube which is more complicated in structure than that just described. The mouth parts of mosquitoes and of bugs (*e.g.* bedbugs, body lice, and plant lice) are also adapted for sucking liquid food. But since these insects live on the blood of animals or the juices of plants, their sucking tongues are fitted also for piercing through the outer skin of animals or the epidermis of plants.

Fig. 266. — Bedbug

Insects, such as grasshoppers, beetles, and caterpillars of moths and butterflies, since they feed on solid food, have biting mouth parts, which consist principally of a pair of hard jaws with sharp cutting surfaces (Fig. 241). These jaws move from side to side rather than up and down. Upper and lower lips are also present.

Summary

Insects have *three body regions:* head, thorax, and abdomen. The *head* has two jointed *antennæ,* two large eyes (compound), and mouth parts for securing food. *Mouth parts* are adapted for *biting* or *sucking* or *piercing and sucking.* The *thorax* has *three pairs* of *jointed legs* and usually *two pairs of wings.* The *abdomen* is always segmented. *Breathing tubes* (tracheæ) run throughout the body. *Veins* are also tubes that are continuous with the breathing tubes.

When an animal in its life history exhibits more or less marked changes in structure and form, it is said to undergo a *metamorphosis.* Butterflies and moths, bees, flies, and mosquitoes have four stages in their life history: egg, larva, pupa, and adult. Such a metamorphosis is said to be *complete.* Grasshoppers and their relatives, on the other hand, have only three stages: egg, nymph, and adult. Such a metamorphosis is said to be *incomplete.*

Structure of Insects

Name	Number and Kind of Wings	Larval Mouth Parts	Adult Mouth Parts
Butterflies, Moths	2 pairs, large, covered with scales	Jaws for biting	Tube for sucking
Grasshoppers	2 pairs, the outer rather stiff and narrow; the inner folded like a fan	Jaws in nymph stage	Jaws for biting
Bees . . .	2 pairs, membranous	Jaws	Jaws for biting and mouth parts for sucking
House flies .	1 pair, gauze	Jaws	Mouth parts for sucking
Mosquitoes .	1 pair, gauze	Jaws	Mouth parts for piercing and sucking

ECONOMIC IMPORTANCE OF INSECTS

NAME	HOW USEFUL OR HARMFUL	METHOD OF EXTERMINATION
Cabbage butterfly	Injures young cabbages	By spraying the leaves with poison
Gipsy moth, Brown-tailed moth, Tussock moth	Injures forest, shade, and fruit trees	By spraying the leaves with poison
Codling moth	Injures fruit	By spraying blossoms and fruit with poison
Silk moth	Spins silk cocoon useful for making clothing	
Honeybee	Makes honey and wax; cross-pollinates the flowers of fruit trees	
Bumblebee	Cross-pollinates red clover	
House fly	Carries certain disease germs	By treating manure with lime; by covering and destroying garbage
Mosquito	Transmits germs of malaria and yellow fever; always a pest	By filling in swamps, marshes, pools; by drainage to keep water in motion; by spraying water with oil

REVIEW QUESTIONS

I. STRUCTURE AND ADAPTATIONS OF BUTTERFLY, GRASSHOPPER, AND BEE

1. Name, locate, and give the characteristics of each of the body regions of each insect studied.

2. Name, locate, describe, and state the number of each of the kinds of organs found on the head.

3. Describe any experiments you have performed or observed in feeding insects.

4. Name, locate, describe, and state the number of each of two kinds of organs found on the thorax.

5. Describe any experiments that show the use of any of the organs found on the thorax.

6. Name and describe each of the stages in the life history of the insects studied.

II. Butterflies

7. To what is the color of the wings due? How may this be determined?
8. Describe the appearance of a scale as seen under the microscope.
9. How are scales held to and arranged on the wing?
10. How are butterflies able to cling to flowers?
11. How may moths and butterflies be distinguished?
12. Name five harmful moths and give an account of the damage wrought by each.
13. Describe the methods and materials used in preventing or reducing the harm done by each of the moths named in 12.
14. Give an account of the silkworm and the industry dependent on it.

III. Grasshopper

15. How is a grasshopper well adapted for jumping? Describe the method of jumping.
16. How are the under wings adapted for flying? What is the use of the outer wings?
17. Locate the breathing pores. Describe the breathing movements. Explain how these movements accomplish the breathing process.
18. Give some facts concerning the harm done by grasshoppers.
19. Name four relatives of the grasshopper.

IV. Bees

20. Name, describe, and state the relative number of each of the three kinds of bees in a colony.
21. What are the functions of the queen and the drones?
22. How are the drones and queens produced?
23. What are the characteristics of worker bees?
24. How is a worker bee produced?
25. Describe the processes of comb building and honey making.
26. State the various ways in which honeybees are useful to man.
27. In what way is the bumblebee useful?

V. Mosquitoes and Flies

28. Give an account of each stage in the life history of a mosquito.
29. How can one distinguish the malaria from the house mosquito in the larval and in the adult stages?

30. In what ways are householders often responsible for a mosquito nuisance?

31. Why should mosquitoes be exterminated, and how in general may they be?

32. Describe in order of importance three methods by which the breeding of mosquitoes may be prevented.

33. Name some of the natural enemies of mosquitoes.

34. Name some diseases the germs of which are carried by the house fly.

35. How is the house fly adapted by structure and habits for carrying disease germs?

36. Give an account of the life history of the house fly.

37. How may house flies be prevented from breeding?

38. How may the family while at home be protected from infection by house flies?

CHAPTER XX

HOW BIRDS ARE RELATED TO HUMAN WELFARE

283. Some questions one may ask about birds. Have you ever thought what would happen to the human race if all birds were to disappear? Would you say that birds are increasing or decreasing in numbers in this part of the country? Do you think it would be possible to get a scientific answer to this question? Are you sure you could distinguish a bird from all other kinds of animals? This, you would find, is not quite so easy as would appear at first sight. Can you explain why birds should interest all of us? Can you tell in what ways birds are most useful to man? Do you know any birds that are harmful to man? In what respects, if any, do the flying machines invented by man resemble birds in the method of flying? Have you any idea how scientists are able to determine the kinds of food and the amount eaten during a year by robins, crows, or other kinds of birds? What do you know from personal observation about the family life of birds? The pages that follow should give you answers to most of these questions.

284. How birds differ from other animals. If you were asked to give the most striking characteristic of birds, you would perhaps say that it is their ability to fly. True it is that nearly all birds possess this power in a greater or less degree; but so do butterflies, bees, and other insects. Have you not also heard of bats, flying fishes, and flying squirrels? You would not of course think of these as birds even though they do possess to some extent the power of moving through the air.

If you have ever held in your hands a living bird, were you not surprised to find it so warm? The temperature

of some of the sparrows and warblers is 12° higher than that of man. While this high temperature is characteristic of most birds, there are some with a degree of heat considerably below 98.6°.

If then neither the possession of wings nor a high temperature is the distinguishing characteristic of this group of animals, is there any way in which every bird is different from every other living thing? We find our answer in the facts that *every bird has a covering of feathers* and *that feathers never develop on any other animal.* Fishes, we found, have a characteristic outer layer of scales, and this is also true of reptiles (snakes, lizards, and alligators). The highest group of animals, on the other hand, the group to which the dog, horse, and man belong, has a body covering of hair.

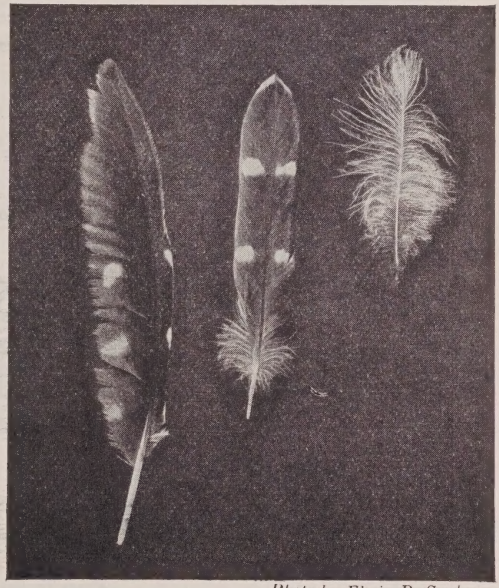
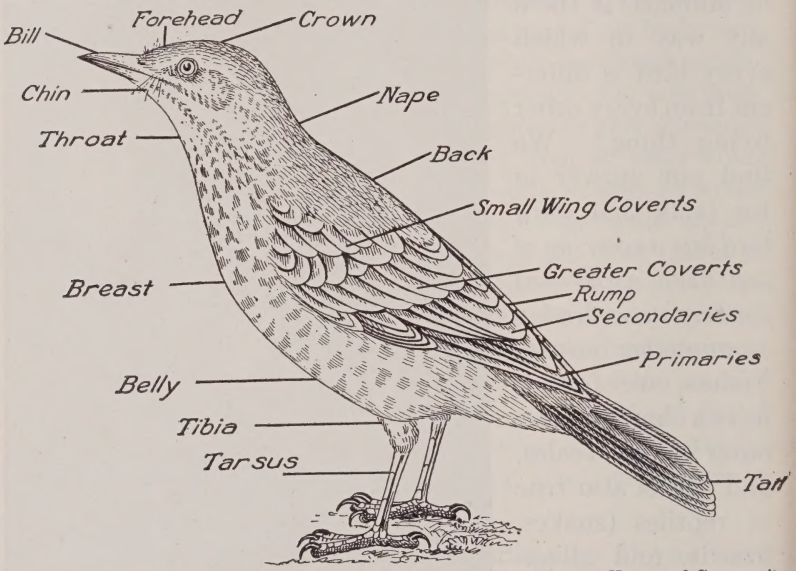


Photo by Elwin R. Sanborn

Fig. 267. — Different types of feathers
At left, wing feather; at right, downy feather; center, tail feather.

285. The head and its organs. Even a brief examination of a bird (Fig. 268) shows us that it has a head, neck, and trunk, and two pairs of limbs; namely, the wings and the legs. A more careful study shows that from the front part of the head projects a horny structure known as the

beak, or *bill*. "Tie a man's hands and arms tightly behind his back, stand him on his feet, and tell him that he must hereafter find and prepare his food, build his house, defend himself from his enemies, and perform all the business of life in such a position, and what a pitiable object he would present! Yet this is not unlike what birds have to do.



From Trafton's Biology of Home and Community

Fig. 268. — Regions of a bird

Almost every form of vegetable and animal life is used as food by one or another of the species. Birds have most intricately built homes, and their methods of defense are to be numbered by the score; the care of their delicate plumage alone would seem to necessitate many and varied instruments; yet all this is made possible, and chiefly executed by one small portion of the bird — its beak or bill." [1]

[1] Beebe's *The Bird*.

Near the base of the bill on either side, one can usually see an opening; these openings are the *nostrils* (Fig. 268). On the sides of the head are the two *eyes*, which bulge out somewhat. As an example of keenness of vision in birds, we may cite the following incident: A kingbird (Fig. 269) was seen by Dr. Oberholser of the United States Biological Survey to start from a telegraph pole, to fly swiftly in a direct line, and to capture an insect so small as to be invisible to the human eye only twenty-five feet away. By actual measurement the distance from which this bird espied its victim was 150 feet. This shows an ability to distinguish objects more than six times that possessed by a human being. If the feathers below and behind the eye are pushed aside, an opening into the *ear* may be seen; this may be made out easily in the head of a chicken. External ears are absent in all birds.

Courtesy U. S. Department of Agriculture

Fig. 269. — Kingbird
Note the insect it has caught.

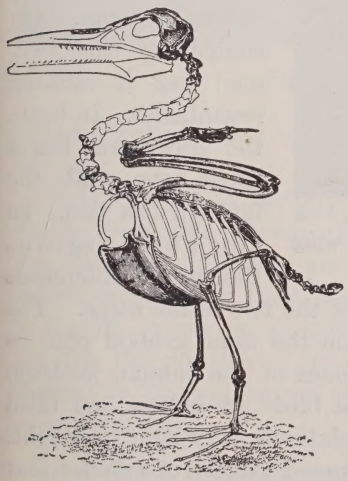


Fig. 270. — Skeleton of a fossil bird

While the size and shape of the bill varies greatly in different kinds of birds, it always consists

of two parts (*mandibles*) (Fig. 268), which correspond in position to the upper and lower jaws of man. When the bill is opened, a careful examination shows that a bird has no teeth. Some of the birds that lived ages ago, however, had well-developed teeth in their jaws, as is shown in Fig. 270, a picture of a bird skeleton restored from bones found in the clay deposits of western Kansas.

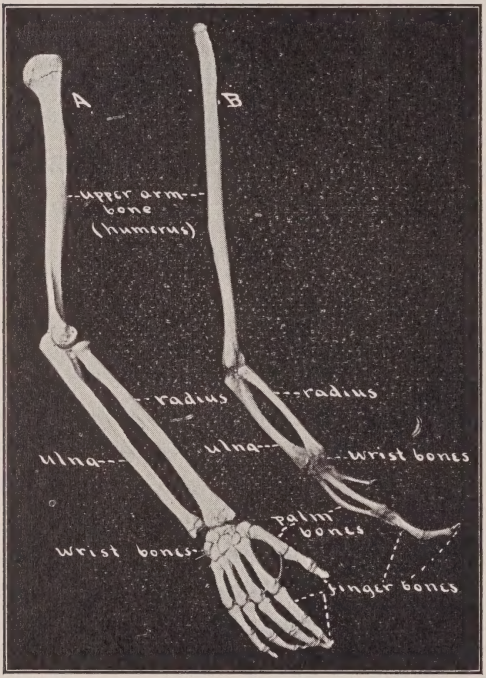


Photo by A. E. Rueff

Fig. 271. — Skeleton of an arm and of a wing *A*, arm of man; *B*, wing of ostrich.

286. How birds are fitted for flight. Fig. 271 shows the bones that compose the wing of an ostrich and the arm of a man. On comparing the two, one sees a striking resemblance. In both, the upper arm has a single bone, while the forearm has two. In the hand region, though the differences are more striking, the general plan of the two is the same. The wings of all birds are constructed on the same general plan as that of the ostrich. Unlike the bones of the human skeleton those of the wings and legs of most birds are hollow and filled with air; hence a bird's skeleton is relatively very light in weight.

The flesh on a bird's wing is composed largely of *muscles* that enable the animal to fold and unfold the parts of the wing, as the

human arm is doubled up or stretched out. On the bird's body are other powerful muscles that cause the wing as a whole to make the downward and upward strokes in flight. When the bird makes the downward stroke, the wings are extended so as to strike against the largest possible surface of air. In the upward stroke the wings are folded back at the elbow; and so when

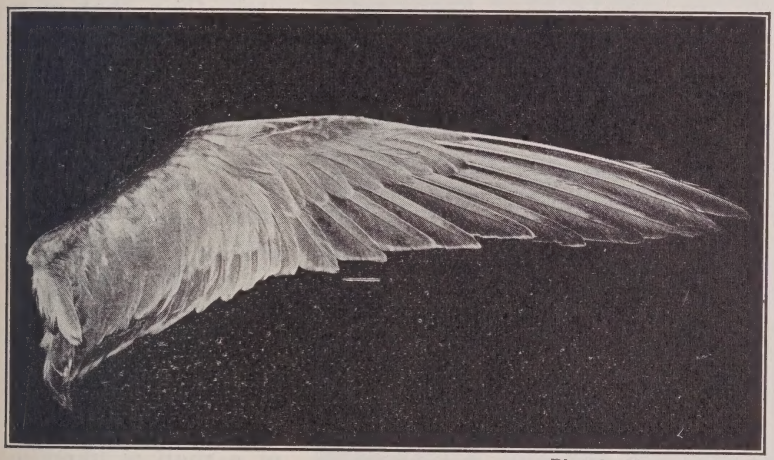


Photo by Elwin R. Sanborn

Fig. 272. — Wing of a tern

raised edgewise, their smaller surface presents little resistance to the air.

Thus we see that the forward-propelling power of a bird largely results from the movements of the wings. In an airplane, on the contrary, the wings are constantly outspread and to a large extent are fixed in their position, and the machine is driven by a rapidly revolving propeller. The bird steers its course by varying the position of its tail feathers. The same principle is applied in the movement of the steering plates in the tailpiece of an airplane.

287. How the legs and feet of birds are fitted for their functions. On comparing the arm of a man with the wing

of a bird, we find that they are similar in general structure in spite of their striking differences in function. Is the same likewise true of the leg and foot of man and of a bird? While the thigh of a bird is much shorter proportionately than that of a man (Fig. 273), in each there is but a single bone. Below the knee of the bird is the shank, or drumstick, which consists of a long bone extending to the ankle, and beside it is a thin bone attached only at the upper end. This region in the leg of a man is likewise composed of a relatively thick shin bone, on the outer side of which is a slender bone extending down to the ankle. The ankle region of the bird is the joint halfway up the leg (Fig. 273). What is commonly regarded as the bird's foot consists of four, three, or two toes that point forward and often one that extends backward. Ordinarily the parts of the leg below the ankle are covered with scales, and the tips of the toes are provided with *nails*, or *claws*.

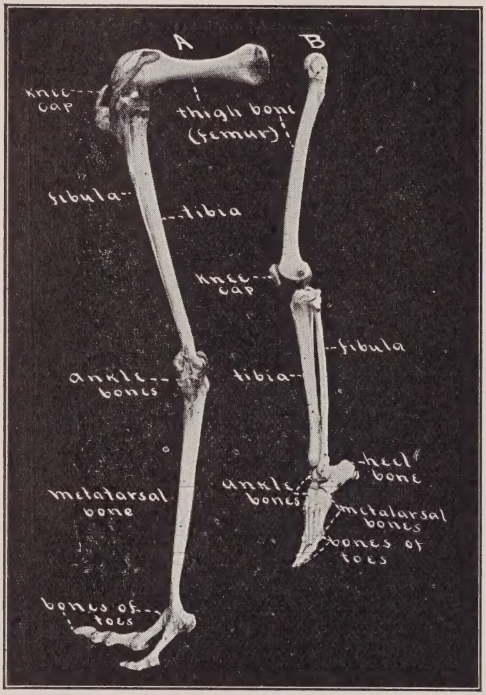


Photo by Elwin R. Sanborn

Fig. 273. — Skeleton of a leg
***A*, leg of ostrich; *B*, leg of man.**

Wings, we have found, are organs specially adapted for flight. Are the legs of a bird likewise limited to a single function? Watch any common song bird (*e.g.* a canary, robin, or sparrow), and you will see that, when it alights on a branch, it clings to this support by clasping it tightly with its three front toes and a single hind toe.

The legs and feet of all birds are likewise used for locomotion. Many of the smaller birds move from place to place by hopping, others by walking, while still other birds (*e.g.* chickens and ostriches) can run with considerable speed. Birds like the herons which wade out into the water in order to secure their food are adapted for this purpose by having remarkably long legs. And finally ducks and swans secure locomotion in the water by means of their webbed feet.

Courtesy of National Audubon Society

Fig. 274. — The great horned owl

Notice hooked beak and sharp talons, used in catching field mice.

The legs of birds are adapted not only for perching and locomotion but also for use in many cases for securing food. This is notably true of hawks and owls, which possess long, sharp, incurving claws, or *talons*, by which they clutch and carry off their prey (Fig. 274). Other birds, such as domestic fowls, have strong nails with which they scratch the ground and thus uncover the insects and vegetable foods which they eat. Most of the members of the wood-

pecker family have two toes in front and two behind, each provided with sharp claws. By the help of these claws they can cling to the trunks or branches of trees and so be in a position to secure their insect food with their barbed tongues after chiselling holes with their long, sharp bills (Fig. 275).

Courtesy National Audubon Society

Fig. 275. — Woodpecker

288. How birds reproduce. Fish eggs, we have found, need no parental care to insure their hatching, for the process goes on when the water is of the right temperature and when other favorable conditions are present. The same is true of the eggs of many other animals, for example, insects, frogs, turtles, and snakes. Birds' eggs, on the other hand, require a degree of warmth that is considerably higher than the ordinary temperature of water and air. This temperature is secured naturally when the parent bird broods over the eggs. In the case of the domestic fowl about three weeks are necessary for the development of the fertilized egg cell into a chick. When the process is completed, the young bird pecks its way out of the shell and is then ready to secure its own food under the direction of its mother (Fig. 279).

289. Of what a hen's egg consists. The outside of the hen's egg is a rather thin, brittle shell, which is lined with a thin, white membrane. A second membrane encloses the liquid portion, or

the *white* of the egg, and in the center is the yellow *yolk*. On the surface of the yolk of a fresh-laid egg is a tiny circular white spot,

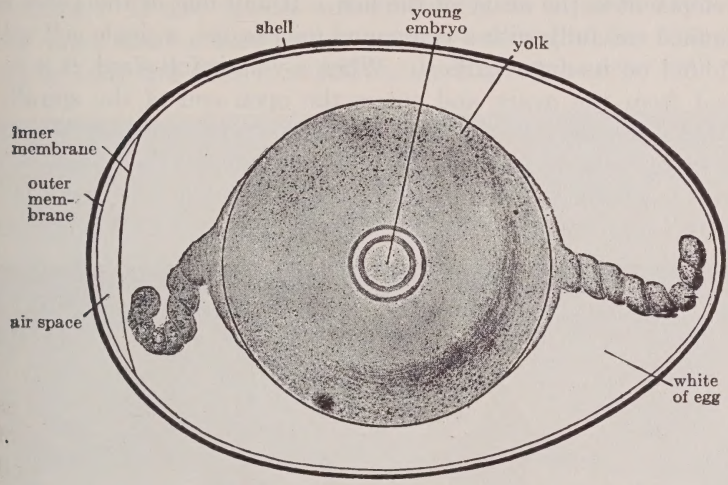


Fig. 276. — Parts of a hen's egg

which can be seen if the shell and the membranes are carefully cut away. This circular spot is the beginning of a chick, and it is the only living part of the egg. The yolk and white of the egg consist of food materials stored up by the mother for use in the development of the baby chick. Let us now see how these various parts of the egg are produced (Fig. 276).

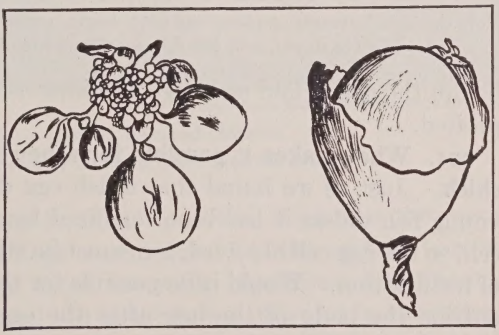
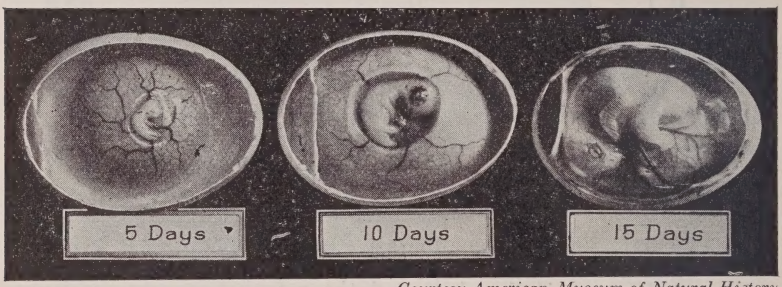


Fig. 277. — Egg-laying organs of a hen

At the left is the ovary with developing eggs; at the right a complete egg in the egg tube.

290. How a hen's egg is formed. If we examine the internal organs of a laying hen, we find a mass of spherical objects, varying

in size from tiny white dots to full-sized yolks that are yellow in color. The yolks and the white dots are eggs in various stages of development in the ovary of the hen. If any one of the yolks is examined carefully with a compound microscope, a single cell will be found on its outer surface. When a yolk is full-sized, it is released from the ovary and enters the open end of the spirally twisted egg tube. As the yolk passes down this tube on its way out, special cells in the tube lining pour out upon it the translucent white, or albumen. Farther down the tube other cells form the two enclosing membranes. And, finally, the hard shell is formed



Courtesy American Museum of Natural History

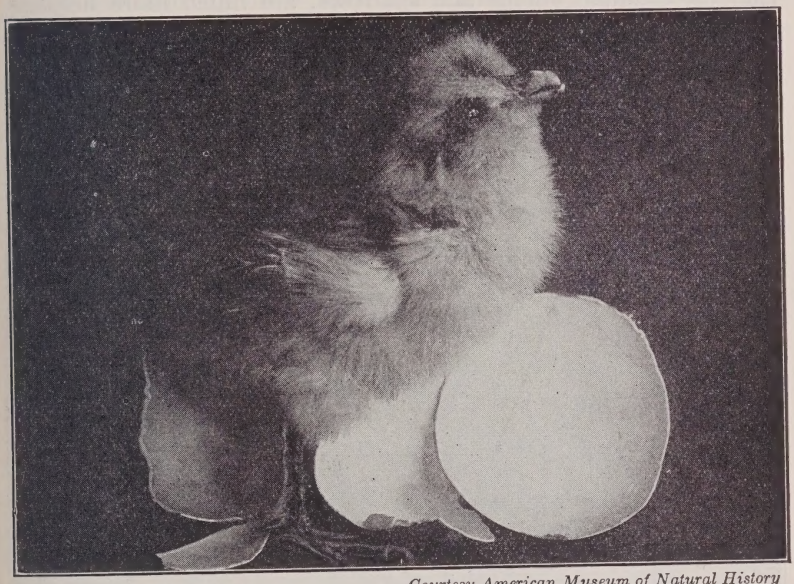
Fig. 278 — Developing embryo of a bird

Note the blood vessels running out from embryo over the yolk (5 days), over the white (10 days), and the decrease in the food supply (15 days).

before the egg is laid although at times soft-shelled eggs are deposited.

291. What makes it possible for a hen's egg to develop into a chick. Just as we found that a fish egg does not develop into a young fish unless it has been fertilized by the nucleus of a sperm cell, so the egg cell of a bird, too, must be stimulated by the process of fertilization. Would it be possible for this process to take place outside the body of the hen after the egg is laid, as is the case with the fishes? Evidently not, since the sperm cells would be unable to penetrate the shell, the membranes, and the white of the egg, before reaching the egg cell on the yolk. Therefore the sperm cell must reach the yolk in the upper part of the egg tube before the rest of the egg is formed.

When a sperm cell reaches and penetrates the egg cell and when the sperm nucleus fuses with the egg nucleus, the egg cell is fertilized. It now divides and subdivides, as it passes down the egg tube, until a many-celled stage is reached at the time the egg is laid, and then it is sufficiently large to be seen with the



Courtesy American Museum of Natural History

Fig. 279. — Newly hatched chicken
Observe the downy feathers that cover the bird.

naked eye. Further development into the chick can not take place unless the egg is kept warm either by the mother hen or in an incubator. When these favorable conditions are present, cell division continues, and the cells become different in character. Gradually the various regions and organs of the bird are formed (Fig. 278), and the chick hatches, that is, it emerges from the shell (Fig. 279).

292. How birds care for their young. In contrast to the animals we have described in Chapter XIII, most birds show a

high degree of care for their young, usually building nests to receive the eggs. The number of eggs that are laid is relatively small. Chickens and quail on hatching from the egg are able to run about and pick up their food under the protection and with the help of the mother bird. Many birds on hatching from the egg, for example, robins and sparrows, are much more helpless

Courtesy National Audubon Society

Fig. 280. — Nest of a fox sparrow
This nest is built on the ground.

than chickens are, and so the food is brought to the young in the nest by the parents. Indeed some parent birds partially digest the food before the young receive it. Parental care and protection from enemies is continued until the birds are able to fly and often for a longer time.

Nests differ greatly in their complexity and in the kind of material used. Birds, such as some of the gulls and many other sea birds, usually deposit their eggs on rocky ledges or in slight

depressions in the sand along the shore. On the other hand, the Baltimore oriole constructs out of grasses, plant fibers, and strings a marvelous nest often high up in the trees near the outer ends of the branches. Between these two extremes are all gradations of nest complexity (Fig. 280).

The *eggs* laid by birds vary also in number, size, and color. For example, the tiny humming bird lays two white eggs about

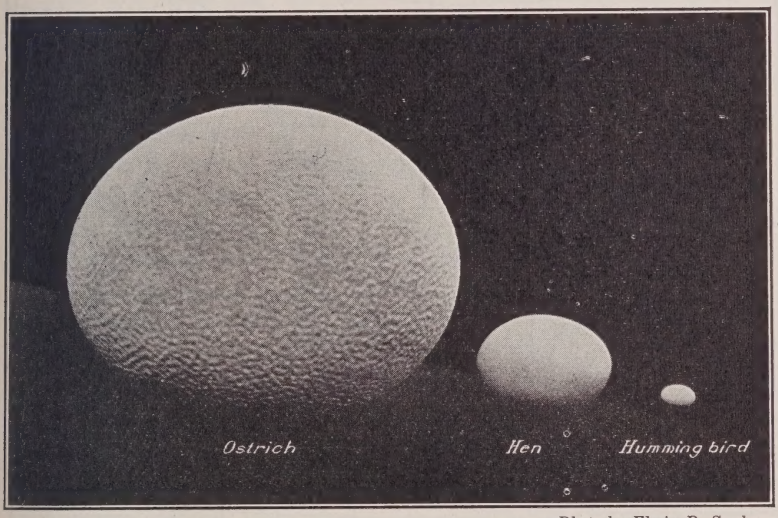


Photo by Elwin R. Sanborn

Fig. 281. — Eggs of birds

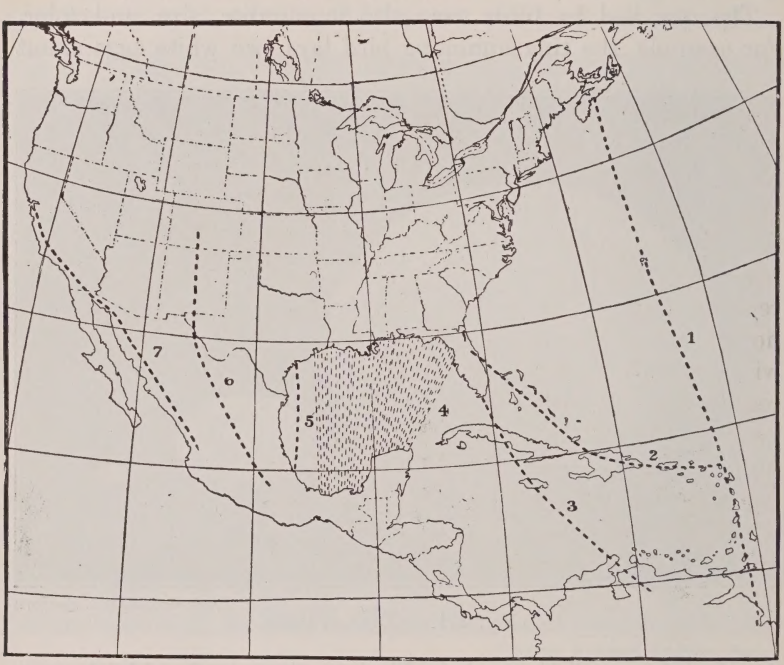
the size of a small bean; the robin lays three to five bluish eggs, each nearly an inch in length, and the ostrich usually lays twelve to twenty eggs, each weighing three to four pounds (Fig. 281). The incubation period in the case of birds varies from ten days (song sparrow) to forty-two days (ostrich).

293. Migration of birds. "For more than 2000 years," says a Government *Bulletin*,[1] "the phenomena of bird migration have been noted; but while the extent and course of the routes traversed have of late become better known, no conclusive answer

[1] See "Bird Migration," *Bulletin No. 185*, United States Department of Agriculture.

has been found to the question, Why do North American birds migrate?"

The various theories advanced to account for bird migration largely have to do with the necessity of securing proper places for nesting and for raising the young. Fig. 282 gives some idea



Courtesy U. S. Department of Agriculture

Fig. 282. — Principal migration routes of North American birds

of the principal routes of travel southward and northward. By far the largest number of our birds follow Route 4 and strike directly across the 500 to 700 miles of the Gulf of Mexico. One of the longest known flights of birds is that of the golden plover, which leaves its breeding place far beyond the tree line, above the Arctic Circle, crosses to Nova Scotia, and thence launches itself over the Atlantic for its long aerial journey of 2400 miles by Route 1 to the coast of South America. After a six months'

vacation from family cares in Argentina it returns across the Gulf of Mexico and thence up the Mississippi Valley to its nesting grounds in the barrens of the Arctic. Thus it completes a round trip of over 16,000 miles!

Courtesy U. S. Department of Agriculture

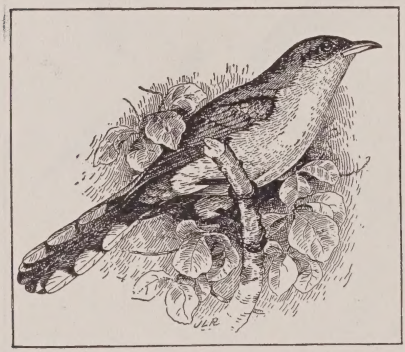
Fig. 283. — Arctic tern

This bird, like the golden plover, makes long nonstop flights in its migrations.

Some of the birds like the chickadee and downy woodpecker remain in the middle and northern United States throughout the whole year and hence are known as *permanent residents* of these regions. Many birds, however, spend the winter in the warmer regions (that is, either southern United States, Mexico, Central America, or South America) and in the spring months move northward. Some of them like the catbird and house wren build their nests, rear their young, and stay all summer in northern and middle United States; hence such birds are called *summer residents*. Still other birds rear their young in Canada, and even farther north, and come to us in the United States as *winter residents*. This seasonal movement of birds is known as *migration*.

294. The value of birds as objects of beauty. Few animals are more beautiful in form and color than are many of our most common birds, and one of the greatest delights of springtime is to greet the return of the bluebirds, tanagers, thrushes, and others

of our feathered friends. "To appreciate the beauty of form and plumage of birds, their grace of motion, and musical powers, we must know them. . . . Once aware of their existence, we shall see a bird in every bush and find the heavens their pathway. One moment we may admire the beauty of their plumage, the next marvel at the ease and grace with which they dash by us or circle high overhead. . . . The comings and goings of our migratory birds in springtime and fall, their nest building and rearing of young, their many regular and beautiful ways as exhibited in their daily lives stir within us impulses for kindness toward the various creatures which share the world with us. . . . But birds will appeal to us most strongly through their song. When your ears are attuned to the music of birds, your world will be transformed. Birds' songs are the most eloquent of nature's voices: the gay carol of the grosbeak in the morning, the dreamy midday call of the pewee, the vesper hymn of the thrush, the clanging of geese in springtime, the farewell of the bluebird in the fall — how clearly each one expresses the sentiment of the hour or season!"[1]



Courtesy U. S. Department of Agriculture

Fig. 284. — Yellow-billed cuckoo

295. How the kinds and amounts of food eaten by birds are determined. The value of birds as objects of beauty can not be measured, it is true, so easily in dollars and cents. But were we to lose the birds, we should realize all too well how much they contribute to the happiness of every lover of nature. When, however, we come to discuss the purely economic value of birds, the good they do can not easily be overestimated.

[1] Quoted from *Bulletin No. 3* of the University of Nebraska, and from Chapman's *Bird Life*.

Whether a bird is beneficial or injurious, however, depends very largely on the kind of food it eats or feeds to its young. If the bird devours great quantities of harmful insects or of weed seeds, to that extent at least the bird is valuable. On the other hand a bird that feeds largely on useful crops, such as fruit or grain, may be considered as injurious.

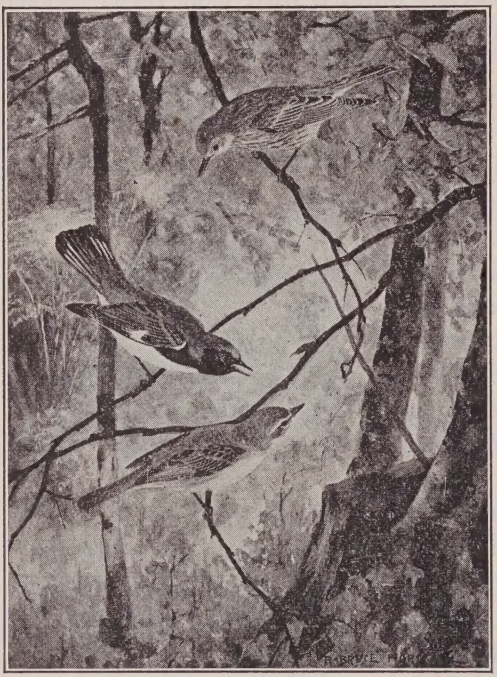
Biologists have carried on long series of studies to determine accurately the food eaten by various kinds of birds. This has been done by watching them while they are eating or while they are feeding their young and by examining the contents of the stomachs of birds. In this way it has been possible to determine fairly accurately the quantities of food consumed by a given kind of bird during a season. The following paragraphs will show the close connection that exists between the nature of the food eaten by birds and their usefulness or possible harmfulness.

Courtesy U. S. Department of Agriculture

Fig. 285. — Swallow

296. How birds are extremely useful as destroyers of harmful insects. Undoubtedly the greatest value of birds to man is the good they do in destroying injurious insects. In Chapter XIX are described some of the ravages made by our insect foes. Following are statements that will give the reader an idea of the enormous value of birds in reducing the numbers of injurious insects:

"If insects are the natural enemies of vegetation, birds are the natural enemies of insects. . . . In the air swallows[1] (Fig. 285) and swifts are coursing rapidly to and fro, ever in pursuit of the insects which constitute their sole food. When they retire, the nighthawks and whippoorwills will take up the chase, catching moths and other nocturnal insects which would escape the day-flying birds. Flycatchers lie in wait, darting from ambush at passing prey and with a suggestive click of the bill returning to their posts. The warblers, light, active creatures, flutter about the terminal foliage and almost with the skill of humming birds pick insects from leaf or blossom. The vireos patiently explore the under side of leaves and odd nooks and corners to see that no skulker escapes. The woodpeckers (Fig. 275), nuthatches, and creepers attend to the trunks and limbs,



Courtesy National Audubon Society

Fig. 286. — Black-throated blue warbler

Note the pointed bills of these insect eaters. The male has darker markings than the two females.

[1] Before this section is assigned for study, each of the birds named should, if possible, be shown to the class. Pictures of the birds may be found in Chapman's *Bird Life* and in leaflets of the National Association of Audubon Societies.

examining carefully each inch of bark for insects' eggs and larvæ or excavating for the ants and borers they hear within. On the ground the hunt is continued by the thrushes, sparrows, and other birds that feed upon the innumerable forms of terrestrial insects. Few places in which insects exist are neglected; even some species which pass their earlier stages or entire lives in the water are preyed upon by aquatic birds."[1]

Courtesy U. S. Department of Agriculture

Fig. 287. — Rough-legged hawk

A friend of the farmer.

"Leading an active life as they do birds require much food and are most ravenous enemies of insect pests. The various groups of birds differ so much in habits that they feed upon practically all groups of insects; hardly an agricultural pest escapes their attacks. . . . In feeding on insect pests not only do birds take a great variety, but they frequently destroy very large numbers. Often more than a hundred individuals are devoured at a meal and, in the case of small insects, sometimes several thousand. With such appetites it is not surprising that occasionally birds entirely destroy certain insects locally. A number of cases are known in which trees, garden crops, and even farm fields have been entirely freed of insect pests by birds. On a 200-acre farm in North Carolina it was

[1] From Chapman's *Bird Life.*

found that birds were destroying a million green bugs or wheat aphids, daily." [1]

297. How birds are useful as destroyers of rats and mice. Hawks and owls with their hooked bills and claws are admirably fitted to clutch and tear living prey. It has been proved that the food of many of these birds consists almost wholly of small gnawing mammals like field mice, which are exceedingly injurious to fields of grain. An examination of the stomachs of fifty short-eared owls showed that 90 per cent of them contained nothing but mice. Forty of the forty-nine stomachs of the rough-legged hawks (Fig. 287) that were examined were found to contain mice while most of the rest contained injurious animals.

Courtesy U. S. Department of Agriculture

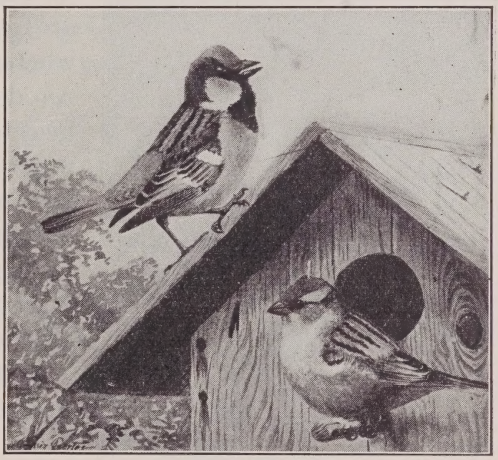
Fig. 288. — Four common sparrows

1, junco; 2, white-throated sparrow; 3, fox sparrow; 4, tree sparrow. Observe the strong conical bills of these seed eaters.

[1] From "Community Bird Refuges," *Farmers' Bulletin No. 1239*, United States Department of Agriculture.

298. How birds are useful as destroyers of weed seeds. Another way in which birds are useful to man is in the destruction of weed seeds. Most perching birds that feed largely upon seeds (*e.g.* sparrows and finches) have strong conical bills, which are especially adapted for crushing seeds. Indeed all the sparrows, with the exception of the English sparrow, are useful in this way.

In one of the pamphlets of the United States Department of Agriculture entitled, "Some Common Birds and Their Relation to Agriculture," the writer estimated that in the state of Iowa during the six months of fall and winter tree sparrows (Fig. 288) devoured 875 tons of weed seed. An actual count of the stomach contents of a bobwhite showed the presence of 400 pigweed seeds. In the stomach of another were 500 seeds of ragweed. It can thus be seen what enormous quantities of harmful plants are prevented by birds.



Courtesy U. S. Department of Agriculture

Fig. 289. — English sparrow

Note the differences between the male (above) and the female (below).

299. Some ways in which birds may be injurious to man. We have discussed briefly in the preceding sections some of the ways in which birds are of incalculable value to man. It must be admitted, however, that some birds are of doubtful value while others are positively injurious.

As an example of a bird, which, to say the least, is a nuisance, we may mention the common English sparrow (Fig. 289). This bird was first introduced from England into the United States at Brooklyn, New York, in 1851, because it was expected to attack some of our injurious insects. These sparrows have multiplied so rapidly that now they are found practically everywhere in the United States. As destroyers of harmful insects, the sparrows are practically useless. Thus, for instance, the stomach of a single cuckoo was found to contain more injurious insects than did the stomachs of 522 sparrows.

Courtesy U. S. Department of Agriculture

Fig. 290. — Crow

But even more serious are the positive charges that have been proved against this bird. It pecks at and destroys the young buds of trees and later injures many fruits while they are ripening. It causes great losses in the grain fields from the time of planting to that of harvesting. Worst of all it molests and drives away our native song and insect-eating birds.

Crows (Fig. 290), contrary to public opinion, are about as beneficial to the farmer as they are injurious: (1) They do much good by the destruction of injurious insects. (2) They are beneficial by the destruction of mice and other rodents. (3) They are valuable occasionally as scavengers.

On the other hand, (1) crows seriously damage the corn crop and injure other grain crops though usually to a less extent. (2) They are very destructive of the eggs and young of domesticated fowls and of wild birds. (3) They do harm by the distribution of seeds of poison ivy, poison sumach, and perhaps other harmful plants.

While most of the hawks are undoubtedly beneficial, two species; namely Cooper's hawk (Fig. 291) and the sharp-shinned hawk, must be kept down to limited numbers. Both of these are "chicken hawks," and in addition they ruthlessly destroy great numbers of our most valuable wild birds.

Courtesy U. S. Department of Agriculture

Fig. 291. — Cooper's hawk
Note the bird it has caught and killed.

300. Some of the dangers that threaten bird life. Certainly enough has been said to show that, all things considered, birds are extremely useful to man. One would, therefore, expect that every possible means would be taken to protect all kinds of valuable birds. Yet what do we find?

"Many valuable forms of wild life (especially of birds) have disappeared within recent years or are now being threatened with extinction. . . . Modern firearms, including repeating or automatic shotguns and rifles, give the hunter an immense advantage over the game. The automobile, better roads, extension of rapid transit, and finally the airplane, enable the hunter quickly to reach the most

isolated places, and have greatly reduced the natural seclusion so essential to the welfare of many game animals. Furthermore, the game laws, in many states still defective,

Courtesy National Audubon Society

Fig. 292. — Destruction of marsh hawks
These are useful rodent destroyers.

are the more easily evaded through the use of these means of conveyance.

"Some conception of the extent to which shooting is carried on may be gathered from reports received through State Game Commissions, which indicate that the number of licensed hunters in the United States in 1919 was 3,598,268. To this number may be added at least 1,500,000 representing those who, hunting on their own lands under

the laws of certain states, require no license and others who indulge in this sport illegally. This makes an impressive total of more than 5,000,000 who go out with a gun every season." [1]

With such an army of hunters abroad in the land, it is

Courtesy Dr. E. H. Forbush

Fig. 293. — The worst enemy of birds

easy to understand the dangers from this source that threaten bird life. In the early days of the white settlements in North America, game birds like the grouse and the duck were abundant and were of necessity killed, as were other wild animals, for food. Later on began the killing of birds for sport. As the forests were cut down, the birds

[1] From "Conserving Our Wild Animals and Birds" by Edward A. Goldman, of the United States Biological Survey, in *Yearbook* of the Department of Agriculture, 1920.

had less and less protection; and had not legislation intervened, the game birds would long since have been exterminated.

301. Destruction of birds by cats. John Burroughs, the

Courtesy National Audubon Society

Fig. 294. — Snowy egret and its young

great naturalist and careful observer, declared that cats probably destroy more birds than all other animals combined (Fig. 293). This statement is confirmed by the President of the National Audubon Societies, an organization that keeps careful census records of birds. Dr. Forbush,

of the Massachusetts Board of Agriculture, is sure that each full-grown cat on the average kills at least 50 birds a year. He adds the following: "Nearly a hundred correspondents, scattered through all the counties of the State (Massachusetts), report the cat as one of the greatest enemies of the birds. The reports that have come in of the torturing and killing of birds by cats are absolutely sickening. The number of birds killed by them in this State is appalling." [1]

In order to check this destruction of our useful birds it is necessary that the cat population should be controlled. All stray cats ought to be caught and painlessly killed. Since the value of cats as destroyers of rats and mice is more than doubtful, cats should not be kept in large numbers for any purpose. No cat should be allowed to roam at large during the nighttime when it is especially likely to steal upon its prey unawares.

302. Destruction of birds for millinery purposes. Even more ruthless than the destruction of birds for food and for sport was, until recently, the killing of birds for millinery purposes. Here the final responsibility rests upon woman alone. A single dealer in the South declared that in the course of a single year he handled 30,000 bird skins, the majority of which were used in the decoration of hats.

The Florida egret (a heron formerly abundant in Florida) was almost exterminated for this purpose. "Twenty years ago," says Chapman, "it was abundant in the South. The delicate aigrettes (Fig. 294), which it donned as a nuptial dress, were its death warrant. Woman demanded from the bird its wedding plumes, and man has supplied the demands. . . . Mercilessly the birds were shot down at their roosts or nesting grounds, the coveted feathers were

[1] From *Useful Birds and Their Protection*, by E. H. Forbush.

stripped from their backs, the carcasses were left to rot, while the young in the nest above were starving."

303. What the effects of bird destruction are. While the esthetic loss to mankind resulting from the destruction of our wild birds can not be computed, yet even in the cities this loss is realized as we see the song birds in the parks steadily diminishing in numbers. Everyone, however, is affected by an increased cost of our food supply, and we have but to review the facts stated in the preceding sections to show that a destruction of our wild birds has a very important bearing on our everyday life.

Every farmer knows that it is impossible to raise the crops of a single year without battling with insect pests. The time and expense involved in applying insect-destroying preparations would be difficult to compute, and even after the year's contest the insects are often victorious. In ruthlessly destroying the wild birds, man interferes with the "balance of nature" and so helps the ravaging hordes of insects and gnawing animals and the weeds as well to multiply without adequate check. All this means that we, the consumers of the grains, the fruits, and the vegetables, must pay higher prices for the food we eat and for the clothes we wear.

304. How protection has been afforded to birds by law. Fortunately the people of the United States have been awakened to the dangers that have threatened our bird life, and Congress and the state legislatures have enacted laws that have long been needed. This has been largely accomplished since 1913. In general it may be stated that with few exceptions it is now against the law to kill at any time anywhere in the United States the insect-eating birds or to kill any of the game birds during the breeding season.

In 1916 an important treaty was signed between the United States and England, the provisions of which protect 537 kinds of migratory birds in our own country and Canada during their migrations north or south. "Under the migratory-bird treaty act, it is unlawful in the United States to hunt, capture, kill, possess, sell, purchase, ship, or transport at any time or by any means any migratory bird included in the terms of the treaty, except as permitted by regulations which the Secretary of Agriculture is authorized and directed to adopt, and which become effective when approved by the President. The act provides police and other powers necessary for its effective enforcement." [1]

Courtesy N. Y. Zoological Society

Fig. 295. — Bird house

A feeding house for birds is shown at the right.

305. How the individual can help to protect birds. But laws, however stringent, are of little avail unless there is a strong public sentiment to bring about their enforcement. Thus it is evident that laws designed to prevent the killing of birds for millinery purposes would be ineffective so long as women were permitted to wear birds on their hats.

[1] Quoted from "Federal Protection of Migratory Birds" by George A. Lawyer, Bureau of Biological Survey, from *Yearbook* of the Department of Agriculture, 1918.

"The importance of engaging the interest of boys and girls in bird life can not be overestimated. It results in a double benefit, for the birds will be held in higher esteem and the youth will become possessed of a source of lasting pleasure. The nest-robbing, bird-shooting boy and the feather-wearing girl may be made the friends and allies of the birds." [1]

But not only should the boy cease to destroy nests and to shoot birds; not only should the girl cease to wear any part of a wild bird; but boys and girls alike should do all they can to induce others to refrain likewise. Much can also be done even in the vicinity of large towns and cities to attract birds and induce them to nest. Stray cats should be kept from harming birds. Pieces of meat, bones, and suet, when hung in the trees in winter time, and crumbs and grains scattered about will serve to attract the winter visitants. When thus attracted, these birds devour great numbers of the eggs and insects in the hibernating stages, insects that during the following season would attack the fruit and shade trees. And finally any ingenious boy can construct and put in the trees bird houses, which in the springtime will become the nesting places of bluebirds, wrens, tree swallows, and martins (Fig. 295).[2]

Summary

A *bird* is a warm-blooded vertebrate, having a covering of *feathers* and wings that commonly enable the animal to fly.

On the head of the bird is a beak, or *bill*, which in modern

[1] Quoted from Weed and Dearborn's *Birds in Their Relations to Man.*

[2] For other methods of encouraging birds see Weed and Dearborn's *Birds in Their Relations to Man*, pp. 304–315; Trafton's *Methods of Attracting Birds;* leaflets of National Association of Audubon Societies, 1974 Broadway, New York City, for example, No. 16 ("Winter Feeding of Wild Birds") and No. 18 ("Putting up Bird Boxes"), 1 cent each; *Farmers' Bulletins*, which can be obtained free from the Department of Agriculture, Washington, D.C. for example, *No. 609* ("Bird Houses and How to Build Them") and *No. 621* ("How to Attract Birds in Northeastern United States").

birds is without teeth. The bill is used for getting food, for protection, and for nest building. It consists of two *mandibles*, and near the base of the upper manible are the two *nostrils*.

The *eyes* of some birds bulge out somewhat from the side of the head. Birds have great keenness of vision. Openings to the *ears* are also at the sides of the head, but external ears are lacking.

Birds are important as *objects of beauty* on account of their lovely plumage, graceful forms and flight, and their delightful songs.

Whether a bird is *useful* or *harmful* depends very largely on what it eats. This has been determined for a large number of birds by watching their feeding habits, determining what food they give to their young, and by examining the contents of their stomachs.

Birds are of greatest value because they feed upon insects that destroy useful plants. Birds also destroy field mice and rats and eat an enormous amount of weed seeds. Nearly all the weed-seed eaters are also insect eaters during the breeding season.

The crow, the English sparrow, and some of the hawks either are injurious, or they do just about as much harm as good.

Dangers that threaten bird life are the following: a steady increase in the number of hunters; more effective firearms; more automobiles for rapid transportation; the removal of forests, hedgerows, and other places of shelter, suited to nest building; cats; and hunters for millinery supplies.

Some effects of bird destruction are these: decrease in the number of birds, increase in the number of insects, of weeds, and of rodents, with a consequent increase in cost to the consumer of all kinds of agricultural products.

Protection of birds is now the policy of most states. It is now against the law to kill any of the insect-eating birds or the game birds during the breeding season. The migratory-bird treaty between the United States and Great Britain protects all migratory birds with such exceptions as are permitted by the Secretary of Agriculture.

The individual can help to protect birds by providing bird houses, by feeding winter residents and permanent residents in times of stress, and by restraining cats especially in the breeding time of birds. The individual should of course refrain from killing birds, from wearing plumage of useful birds, and from destroying the nests and eggs of birds and should do all he can to influence others to follow the same course.

REVIEW QUESTIONS

1. How do birds differ from other animals?
2. Name, locate, describe, and give the function of each of the kinds of organs found on the head of a bird.
3. Discuss the value of birds as objects of beauty.
4. How are the kinds and amounts of food eaten by different kinds of birds determined?
5. Give an account of each of the three ways in which wild birds are of most use to man with examples and wherever possible with statistics.
6. In what ways may some birds be injurious to man? Give examples.
7. State some of the dangers that threaten bird life.
8. Discuss the slaughter of birds by cats; by hunters for millinery supplies.
9. What should be done to check the destruction of birds by cats? By hunters?
10. State some of the effects of bird destruction. How are all of us affected by this bird destruction?
11. In what ways has the protection of law been extended to birds?
12. What have the United States and Great Britain together done to protect the migratory birds?
13. In what ways can the individual protect birds and encourage them to breed?

CHAPTER XXI

HOW MAMMALS ARE RELATED TO HUMAN WELFARE

306. What a mammal is. One would hardly suppose that animals as different as the ocean-dwelling whale (Fig. 17), the flying bat, the enormous elephant (Fig. 304), the tiny mouse, and the domestic horse could all be included in a single class. Yet such is the case. For as a bird can be distinguished from all other animals by its covering of feathers, so all the animals named above and all of their relatives are alike in that they have a *covering of hair.* The texture and density of this hairy coat, however, vary greatly among the forms enumerated. On the whale the hairs are as few and as far between as they are on the shining heads of some of our human acquaintances. On the Northern musk ox (Fig. 296) the shaggy covering is so long that it almost reaches to the ground. Furthermore, the amount of hair on some animals varies greatly at different times of the year. Those of us who are familiar with the horse know that at certain seasons the hair falls out and a new coat appears — a process that resembles the molting of birds.

Again, all the animals named above, and many others, develop their young within the body and feed their young for a time after birth on milk secreted in milk, or *mammary, glands.* Because of the possession of these glands the animals of this class are known as *mammals.* This method of feeding their young is of course familiar to us in the case of the cow, dog, and other domesticated animals; but it may

not be so well known that seals, whales, and porpoises likewise feed their young on milk. Female opossums and kangaroos, after the young are born, put them into pouches on the lower front part of their body (Fig. 297). The pouch not only serves as a means of protection, but also as a place for feeding the offspring, since within it are the mammary

Courtesy N. Y. Zoological Society

Fig. 296. — Musk ox

These animals subsist largely on the scanty vegetation that is found beneath the snow.

glands that secrete the milk needed by the young, which are very immature at birth. A still more unfamiliar mammal, which like the kangaroo inhabits Australia, is the duckbill (Fig. 298). Although this animal is covered with hair and secretes milk for its young, it is like the birds in that it lays eggs from which the young are produced.

A third distinguishing characteristic of the mammals is

the presence of a *diaphragm* (Figs. 95, 96), which separates the chest cavity from the abdominal cavity. This structure is absent in all other animals. Most mammals too have a body temperature about like that of man, whether like the polar bears and Arctic foxes they live in the frozen

Courtesy N. Y. Zoological Society

Fig. 297. — Kangaroo and its young

regions of the Far North or like the tigers and elephants they inhabit the tropical jungles.

We may, therefore, say that a *mammal is a warm-blooded vertebrate that feeds its young on milk and that has a hairy covering and a diaphragm.* Most of the mammals have a distinct head, neck, trunk, and tail and two pairs of appendages. In man, however, and in manlike apes the tail is lacking. Mammals are found in all parts of the world,

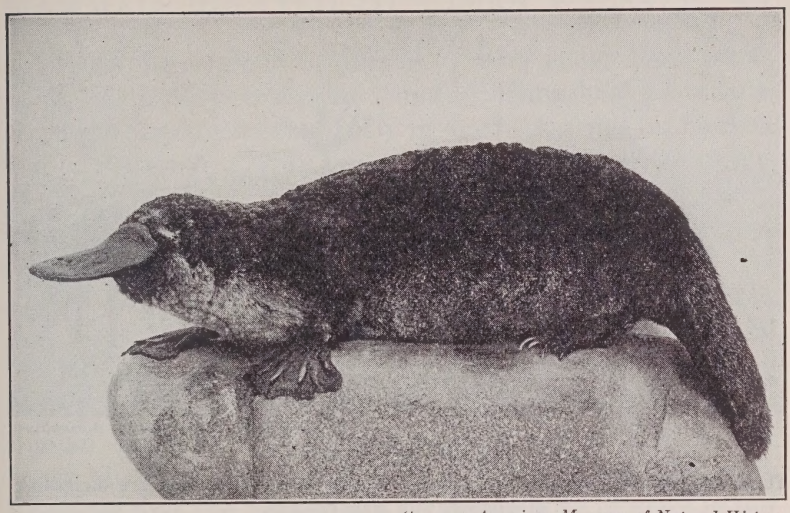
with the possible exception of some of the islands of the Pacific Ocean.

307. Mammals as beasts of burden. Man has made large use of mammals as beasts of burden. The most familiar type is the horse. This animal and its near relatives, the donkey and mule, have been used for thousands of years. By careful selection and breeding such different types of horses have been developed as the small Shetland pony, the draft horses used for hauling heavy loads, and the trotting and racing breeds that have made astonishing records for speed. Among the wild relatives of the horse is the zebra.

The camel with its cushionlike feet is particularly fitted for carrying burdens across sandy regions (Fig. 299). For this reason this animal has been frequently referred to as the "ship of the desert." As such it has played an important part in the history of the Old World, especially among the nations of the East. Not only is the camel adapted by the shape of its feet for desert travel, but also its stomach has a large number of pockets (water cells) that are able to hold enough water to last the animal for days.

As the camel is the beast of burden of the tropical deserts, so the reindeer (Fig. 300) may be regarded as specially fitted to provide means of transportation in the Arctic regions. These animals have wonderful ability to thrive on the poor food furnished by lichens and to endure extremes of cold. Esquimo dogs too are of great value, being used in hauling sledges. These two animals fulfil all needed requirements of those northern dwellers who depend so much on their aid.

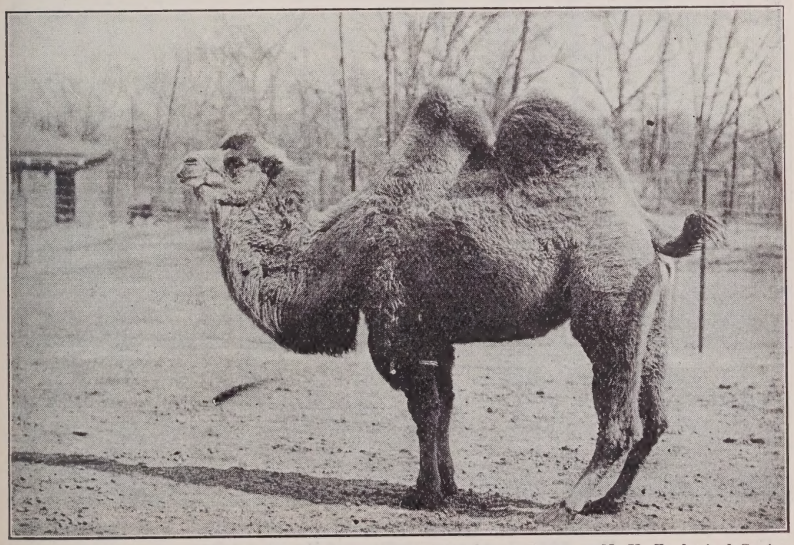
Another mammal that seems wonderfully adapted as a beast of burden is the sure-footed llama, used over difficult mountain passes of the Andes (Fig. 301). In the Eastern



Courtesy American Museum of Natural History

Fig. 298. — Duckbill

In what ways does this animal resemble a bird? For what reasons is it regarded as a mammal?



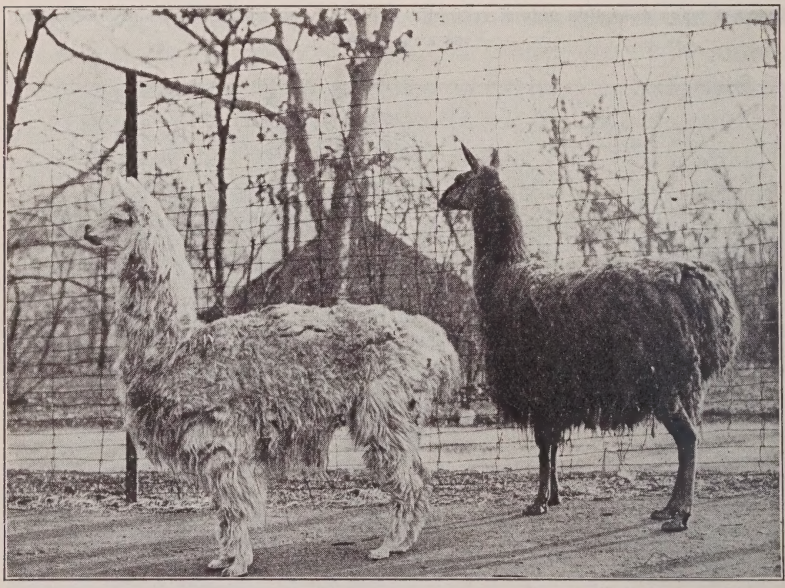
Courtesy N. Y. Zoological Society

Fig. 299. — Camel

Courtesy U. S. Department of Agriculture

Fig. 300. — Reindeer

These animals have been introduced into Alaska from Siberia and are increasing in numbers with great rapidity.



Courtesy N. Y. Zoological Society

Fig. 301. — Alpaca (left) and llama (right)

countries the elephant is trained to carry heavy loads on its back. It uses its muscular trunk in lifting heavy burdens. Oxen are employed extensively in most countries for hauling heavy materials. This they do usually in pairs by means of a yoke that fits over their necks, the weight that is drawn pressing against the top of the neck and the front of the shoulders.

308. Mammals as sources of food. Most kinds of mammals with the exception of some members of the cat and weasel families are used as food by some of the races of the earth, and this is perhaps their most important relation to human welfare. The hoofed animals are of first importance since to this group belong cattle, sheep, and pigs. Consider first the importance of the millions of cows in our country in the production of milk, from which butter and cheese are also made. So far has biology been applied to human welfare in the dairy industry that the modern farmer is able to breed cattle especially fitted to produce milk either especially rich in butter fat or great in quantity.

The immense importance of cattle as a source of beef, or when killed young as a source of veal, needs only to be mentioned to be realized in some degree. Likewise, sheep are eaten as lamb or as mutton, and pigs furnish us with pork, ham, bacon, and lard. So highly developed has become the modern slaughtering and packing industry that it is said that practically every part of the animal is utilized. Among the other mammals used by man for food we may mention rabbits, squirrels, bears, deer, and opossums. The seal, walrus, caribou, and muskox (Fig. 296) are valued as food in the Arctic regions and especially for the supplies of needed fats which these animals furnish.

309. Mammals as sources of clothing. Next in importance to the food furnished to man by mammals, we may

name the value of this group of animals as a source of clothing. Sheep have been introduced in enormous numbers into all civilized countries not only for their flesh as food but also for the wool that they furnish, which is of such a texture that it can be woven into cloth of great warmth. The wool of the alpaca (Fig. 301) is also a source of clothing. The hides of cattle, goats, horses, walruses, and

Fig. 302. — Herd of seals on Pribilof Island

other mammals are tanned; that is, toughened by chemical treatment, and thus converted into leather, which is most valuable to man.

Off the coast of Alaska are the Pribilof Islands, the breeding place of the Alaska fur seals (Fig. 302). This animal, most valuable as a source of furs, was in grave danger of extinction before the United States Government succeeded in enforcing prohibition of open-ocean killing.[1] Too late, alas,

[1] For an account of the seal slaughter, read Jack London's *Sea Wolf*.

are we awake to the fact that the American bison (commonly called the buffalo) has become extinct over nearly all its former range. These animals, in the early history of our country, roamed the Western plains in countless numbers, and their hides were of great value because of their dense curly hair.

The list of fur-bearing mammals of value to man is a

Fig. 303. — Skunk

long one. It includes, among others, the muskrat, bear, opossum, mink, otter, beaver, skunk (Fig. 303), mole, squirrel, raccoon, fox, and seal. Some of these (*e.g.* foxes and skunks) are bred in captivity. It is becoming a grave question, however, whether the enormous demand of women for the furs of wild animals, not only for winter warmth but also for summer adornment, will not bring about the early extinction of some species.

310. Mammals as sources of other valuable commercial products. Besides their value to man as a means of transportation and as a source of food and clothing, mammals furnish us with valuable commercial products. From the tusks of elephants (Fig. 304) and walruses comes the precious ivory. Hoofs, horns, blood, and bones are used in the manufacture of buttons, ornaments, handles, glue, and gelatin. Bone black is used in refining sugar. The fine hair of camels is largely employed for soft paint brushes, and the coarser bristles of pigs are made into brushes for other uses.

Blood and other parts of animals not used for other purposes are sold by the packing houses for the manufacture of fertilizer. In former days, before the discovery of kerosene and before electric lighting was thought of, the whaling industry was of immense importance. The whole outer surface of these huge sea monsters consists of a thick layer of fat, or *blubber*, from which the whalers extracted great quantities of oil, most useful in those early days for illumination.

311. Mammals injurious to man. Many uses of mammals to man besides those mentioned might be enumerated. But we must not forget that this, the highest group of animals, also contains numerous forms that are partly or wholly injurious. As examples of kinds of mammals for which not a single good word can be said, we may mention rats and mice. "The rat is the most destructive animal in the world," writes Dr. Lantz of the United States Department of Agriculture. This authority estimates that in the United States alone rats destroy each year $200,000,000 worth of property. Let us now see how this is possible.

In the first place, where food is plentiful, rats may breed six to ten times a year and may average ten young in each litter. These animals feed and reproduce in the open fields

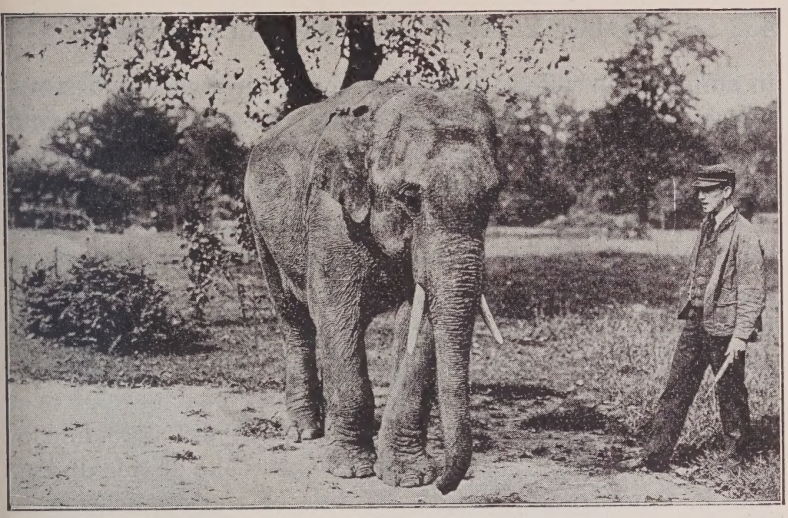


Fig. 304. — Elephant

This is one of the most intelligent of animals in spite of the fact that its brain is relatively small.

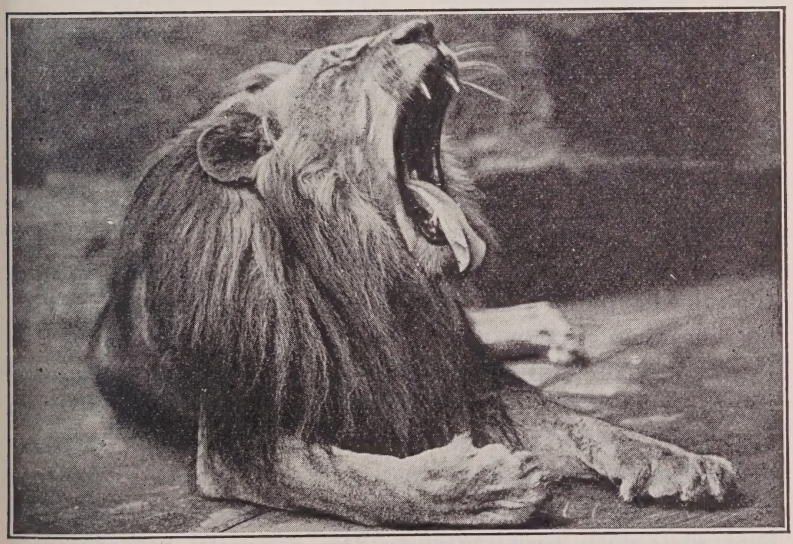


Fig. 305. — "King of beasts"

Note the greatly developed canine teeth and the powerful claws.

in summer; in winter they seek shelter in barns and storehouses. Hence they are exceedingly destructive to standing grain or to grain that is stored and to foods prepared for man in stores and houses.

But perhaps the worst indictment brought against these pests is the fact that rats are an agency for carrying disease germs. The terrible *bubonic plague* is a disease that results from germs carried to human beings by a flea which infests rats. Hence it is always a filth disease that is preventable. The *black death* of the fourteenth century which swept over Europe and killed 25,000,000 people was an epidemic of bubonic plague. One of the latest outbreaks of this disease was in San Francisco. As a result of the application to human welfare of known biological principles only 77 deaths occurred before the disease was stamped out by local extermination of the rat.

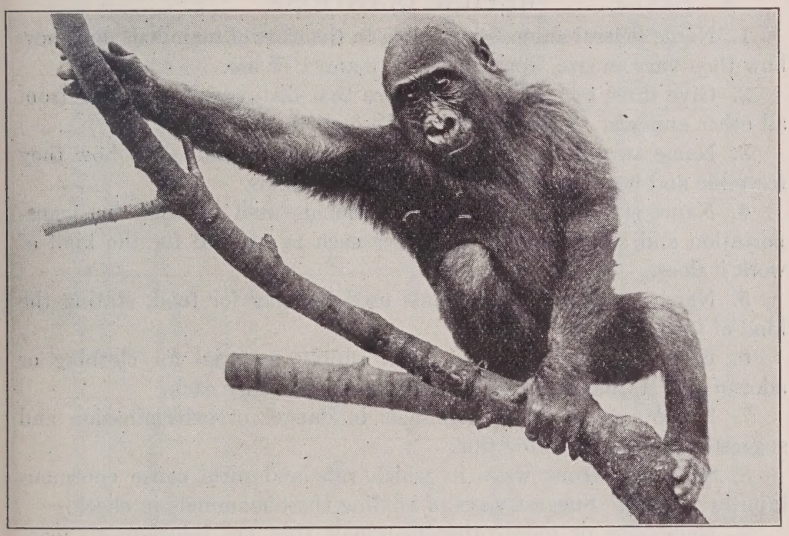
It is evident then that the individual and the public should take every possible means to starve the rats during the winter at least by careful storing of food and to catch as many of them as possible by means of traps. House mice and field mice likewise are destructive and they should be exterminated.

The rabbits are relatives of the rats and mice. Introduced into Australia, they bred with such astonishing rapidity that the people of that country have had great difficulty in keeping them in control. Prairie dogs likewise belong to this family of gnawing animals. In eleven states west of the Missouri River they are so numerous that their burrows and their destruction of crops cause a serious drain on agricultural production.

In our study of birds we called attention to the havoc cats play with birds, and to the necessity for checking their depredations. Relatives of the cat, the African lion

(Fig. 305) and the tiger, often attack man and his flocks. Wolves and bears too often become ferocious, especially when food is scarce.

312. The highest order of mammals, the primates. There remains one other group of mammals of which we should speak; namely, the highest, that to which man belongs.



Courtesy N. Y. Zoological Society

Fig. 306. — Gorilla

This largest and fiercest of the apes inhabits a small area of the tropical forests of West Africa.

This group also includes the monkey, the baboon, and the ape. To the latter group belong the orang-outang, the chimpanzee, and the gorilla (Fig. 306). Because these animals excel the rest of the animal kingdom in brain development and in intelligence, this order of mammals is known as the Primates (from the Latin, meaning *first*). Some of these animals, "while resembling the human species in many

characteristics, must of course be recognized as having evolved (developed) along special lines of their own, and none of them are to be thought of as the source or origin of the human species. It is futile, therefore, to look for the primitive stock of the human species in any existing animal." [1]

REVIEW QUESTIONS

1. Name several animals belonging to the class of mammals and show how they vary in size, appearance, or manner of life.
2. Give three or four characteristics that distinguish mammals from all other animals. Discuss each of these characteristics.
3. Name two distinctive mammals of Australia and show how they resemble and how they differ from other mammals.
4. Name six different kinds of mammals used by man for transportation and show some of the ways each is adapted for the kind of work it does.
5. Name six kinds of mammals used by man for food, stating the kind of food supplied by each.
6. Enumerate ten mammals that supply material for clothing or adornment, stating the kind of material supplied by each.
7. Name several useful mammals in danger of extermination and suggest ways of preventing this.
8. Show numerous ways in which rats and mice cause enormous injuries to man. Suggest ways of holding these mammals in check.
9. Name five or more other mammals that are injurious to man, stating how each is injurious.
10. What animals belong to the order of mammals known as Primates? Why are they so called?
11. In what ways is man superior to all other members of the animal kingdom?

[1] From Osborn's *Economic Zoology*.

Comparative Outline of Reproduction in Many-celled Animals and Plants

Kind of Plant or Animal	How the Sperm Cell Reaches the Egg Cell	Where Fertilization Takes Place	Where the Embryo Develops	How the Embryo Is Fed	Relative Number of Eggs That Develop and of Young That Survive	Degree of Parental Care
Fern	By swimming through moisture on surface of prothallus	In egg case (*archegonium*) of prothallus	In egg case of prothallus	From food manufactured by parent prothallus		
Flowering plant	By insect or wind pollination and by germination of pollen grain	In ovule of ovary	In ovule	From food manufactured by parent flowering plant		
Fish	By swimming through water	In the water where eggs are laid	In water where eggs are laid	From food stored in yolk by female parent	Enormous number of eggs laid; few of young survive	Usually none
Bird	By swimming through mucus that lines egg tubes	In the upper regions of egg tubes	Inside egg, after it is laid and incubated	From food stored in yolk and white by female parent	Relatively few eggs laid; most of young survive for a time at least	Marked degree; nests built, eggs incubated, young fed, and protected after hatching by one or both parents
Mammal	By swimming through mucus that lines egg tubes	In the upper regions of egg tubes	Inside a sac at the lower end of egg tubes	From blood vessels attached to placenta within sac	Relatively few eggs discharged and fertilized; most of young survive for a time at least	Marked degree; embryos fed before birth; young supplied with milk and protected after birth

PART IV

ADDITIONAL BIOLOGICAL STUDIES

CHAPTER XXII

HOW SINGLE-CELLED ANIMALS CARRY ON THEIR FUNCTIONS

313. How material is obtained for the study of single-celled animals. One way of securing an abundance of material for the study of single-celled animals is to cut a handful of hay into pieces, put it into a quart fruit jar or battery jar, and add plenty of water obtained from natural bodies of fresh water, that is, water from pond, creek, or swamp. This "hay infusion" should be allowed to stand for a few weeks. On examining the mixture with a low power of the microscope, a wonderful scene of life is revealed. Our attention is fixed upon a multitude of tiny living forms that hurry across the field of our vision. Among these we shall probably find the single-celled *Paramecium* which we are now to study. The hay is added to the water to furnish food for the still smaller living organisms (bacteria) on which Paramecium feeds. Since these animals will not develop unless individuals of the same kind are present, we can see the reason for securing the water from swamps or ponds, since the public water supplies are frequently treated with chemicals that destroy plant and animal life.

314. What the structure of Paramecium is. In form Paramecium resembles somewhat the shape of a slipper, hence it is sometimes called the "slipper-shaped animalcule" (Fig. 307). Extending from all parts of its outer surface are many tiny projections of protoplasm that look like colorless hairs; these are known as *cilia* (singular *cilium*). In locomotion the animal usually moves with the blunt end (*i.e.* heel of the slipper) in front, being propelled by the swifter backward strokes of the cilia and a slower recovery. When Paramecium runs into an obstacle, the action of the cilia is reversed, and thus the animal is enabled to move with the opposite end (toe of the slipper) in front. Most

animals that swim (*e.g.* fishes and frogs) have broad and flat appendages that are comparatively large. In Paramecium, on the other hand, the organs of locomotion (cilia), while slender, are so numerous that they accomplish the same purpose as the broad swimming appendages of the frogs and fishes.

315. How Paramecium secures and digests its food. Paramecium feeds upon one-celled plants and animals. On one side of the animal is a furrow, or *groove*, which is lined with cilia (Fig. 307). At the lower end of the groove is an opening, the *mouth*, which leads into a short tubular *gullet*. The rapid inward motion of

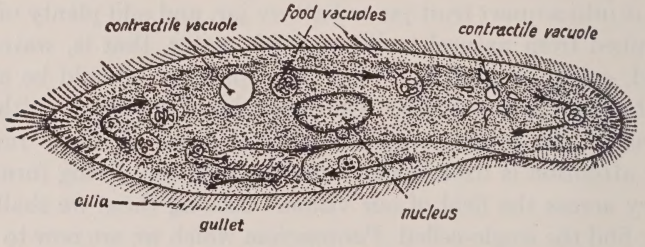


Fig. 307. — Paramecium
Note the striking resemblance to a slipper.

the cilia in the groove draws the food toward the mouth and other cilia lining the gullet push down the food particles. Small collections of these food particles are made at the lower end of the gullet, and these masses, *food balls*, are circulated within the cell by the streaming movement of the protoplasm.

As the food balls circulate through the protoplasm, they are gradually digested by ferments made by the protoplasm, and the food materials thus liquefied are used, as in plants and other animals, for the production of more protoplasm, or for the release of energy needed for locomotion and for food getting. The indigestible parts of food are forced out through an opening that appears in the side of the body.

316. How Paramecium carries on respiration and excretion. Since Paramecium is surrounded by water that contains oxygen, this can pass into the protoplasm by diffusion through the thin

membrane surrounding the animal. When the oxygen combines with chemical elements found in foods or protoplasm, oxidation is carried on, energy is released, and waste substances are formed. The carbon dioxid diffuses outward into the surrounding water through the outer layer of the animal.

In each half of the animal is a clear space which is circular and accompanied by smaller spaces, which together have at times a star-shaped appearance. These are the *contractile vacuoles.* The liquid wastes formed by oxidation collect in these vacuoles. The protoplasm then periodically presses upon the vacuoles, and the waste materials are squeezed out of the animal into the surrounding water. When this occurs, the contractile vacuoles disappear for an instant. They then slowly refill. These vacuoles also probably help to keep Paramecium from bursting from the internal pressure resulting from osmosis.

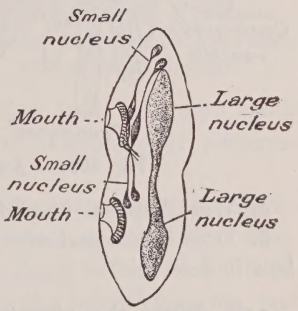


Fig. 308. — Paramecium reproducing

317. How Paramecium reproduces its kind. In the interior of Paramecium are two nuclei, known as the large nucleus and the small nucleus. Both of these show readily when the animal is stained with iodine or with other chemicals. When the animal reproduces, the nuclei divide in halves (at least in one species of Paramecium), a new mouth and gullet are formed, and two new contractile vacuoles appear (Fig. 308). The cell body then divides transversely, the cells separate from each other, and thus from a single individual two new individuals are formed. If conditions are favorable, both animals grow and may in turn reproduce at the end of twenty-four hours. It has been estimated that a single individual may be responsible for the production of 268,000,000 offspring in one month. Actually, however, this never takes place, for the necessary food, oxygen, and other favorable conditions would soon cease to exist. In the "struggle for existence" many individuals would die, and only those that are strongest would survive.

EXERCISE 61

Study of Paramecium. Laboratory study.

On a glass slide, by means of a pipette or glass tube, put a drop of the hay infusion containing Paramecium. Study the preparation with the low power of the compound microscope.

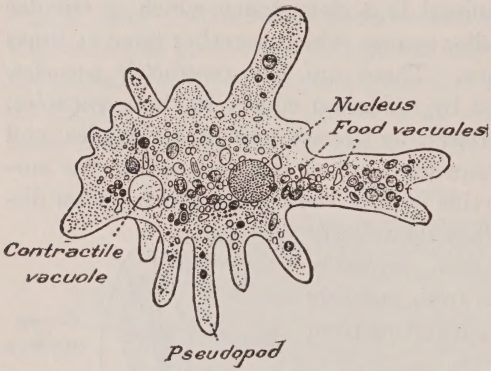


Fig. 309. — Amœba

1. What is the color of the living animals?
2. Do they seem to swim slowly or rapidly? Do they really swim as rapidly as they appear to? Give a reason for your answer.
3. Is the more pointed end or the rounded end of the animal usually foremost in swimming?
4. What happens when Paramecium strikes an obstacle?
5. Does the animal ever rotate on its long axis? If so, can you tell how it does this?

318. What the structure of an amœba is. When we study with the compound microscope some of the mud, decaying leaves, or other sediment obtained from the bottom of a pool of water, or even in a hay infusion, we may be fortunate enough to run

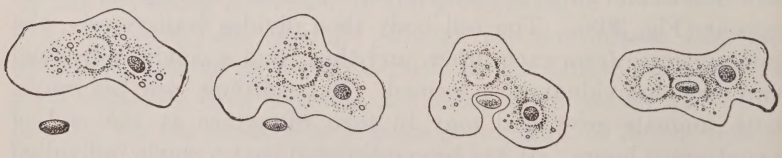


Fig. 310. — Amœba eating

Note that the particle of food is gradually engulfed by the flowing protoplasm.

across specimens of another most interesting form of single-celled animal, known as the *amœba* (Fig. 309). This minute creature is a droplet of semifluid, more or less colorless protoplasm. It

may be somewhat spherical in form; but as we look at our specimen, we note that its shape is changing (Fig. 310). On one side some of the material of which the amœba is composed is slowly streaming out to form projecting processes, which vary in size and shape. Each of these extensions is called a "false foot," which may increase in size until all of the substance of the animal has passed into it. By pushing out these processes in front and pulling up its body matter from behind, the amœba moves slowly from one part of the slide to another. If we suddenly jar the slide, all the protoplasm in the extended false foot is drawn back toward the center of the animal, and the amœba again assumes its spherical form.[1]

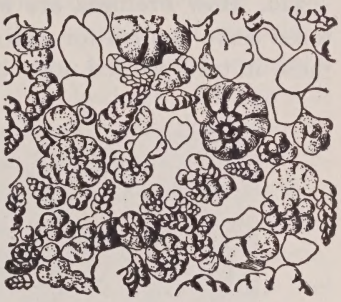


Fig. 311. — Shells of protozoa
Shells like these form the white chalk cliffs of Dover, England.

319. What the likenesses and the differences between Paramecium and amœba are. Both are animals so small that they can barely be seen with the naked eye. Both live in water, both are one-celled animals, and both carry on the same functions, but in a somewhat different manner. While Paramecium maintains a relatively fixed form, the amœba is capable of assuming almost any shape. Paramecium has two nuclei and two contractile vacuoles; an amœba, on the other hand, has only one of each.

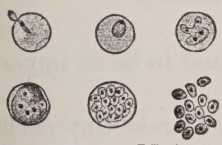


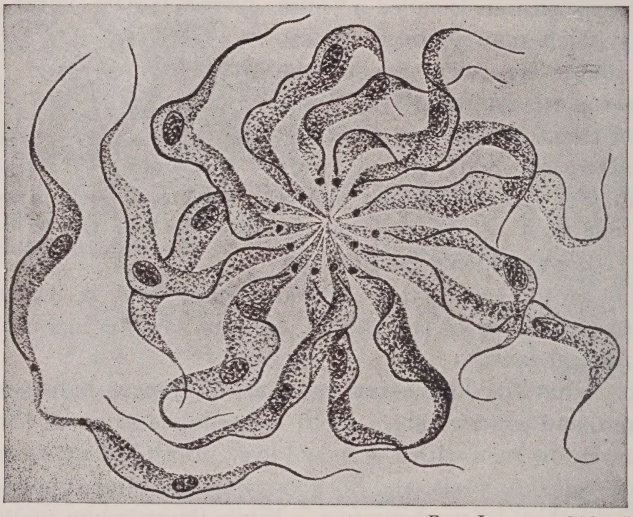
Fig. 312. — Malaria germ
Growth and division within the red corpuscle.

Unlike Paramecium, the amœba has no definite part of the body through which it takes in food. When this animal is feeding, it slowly flows about the one-celled plant or animal and finally engulfs it (Fig. 310). The processes of digestion, assimilation, respiration, excretion, and reproduction are much the same in both. These organisms belong to a group of animals known as

[1] For reproduction of amœba see 163.

the Protozoa (from the Greek, meaning *first*, or *primitive*, *animal*).

320. How Protozoa are important to man. Most of the Protozoa serve as food for other animals that live in the water, and these in turn are fed upon by fish, which may be eaten by man.



From Laveran and Mesnil

Fig. 313. — Organisms similar to these cause sleeping sickness
Sixteen individuals very highly magnified are shown.

Thus the one-celled plants and animals are found to be an important food basis for human beings.

Some of the Protozoa that live in the sea secrete tiny shells (Fig. 311), and, when the animals die, the shells drop to the bottom. As a result of heat, pressure, and other causes, this bottom "ooze" is gradually solidified to form chalky rocks. In the upheavals of the ocean bottom that have taken place in the ages past, these rocks have often been forced above sea level. The chalk cliffs of Dover, England, were formed in this way.

While most of the Protozoa are harmless, there are a few forms

that have become parasitic in human beings. Malaria is due to a protozoan resembling an amœba in form. This parasite, as we have already learned, is carried from one victim to another by the female Anopheles mosquito. When this organism of malaria is present in human blood, it bores its way into a red corpuscle (Fig. 312), feeds upon the contents of this blood cell, and grows at the expense of the corpuscle until the parasite occupies nearly all the space inside it. The malaria parasite then divides into a number (6–16) of daughter parasites, which rupture the red corpuscle in which they have been developing and escape into the liquid part of the blood, thus causing the chills so characteristic of malaria. Each new parasite then attacks a new corpuscle and at the end of two or three days produces six to sixteen new spores, and so the organisms multiply. For the treatment of malaria quinine is the most effective drug known at present. It should be taken in the quantity and at the times prescribed by the physician.

Another form of Protozoa causes the terrible disease known as sleeping sickness of tropical Africa (Fig. 313). This single-celled animal is transmitted from one sufferer to another by a kind of fly known as the tsetse fly. Tropical dysentery is also caused by a protozoan.

CHAPTER XXIII

CRAYFISH AND THEIR RELATIVES

321. Habits of crayfishes. Crayfishes are found commonly throughout the United States in rivers and their tributaries where limestone is found, since lime is needed in making their hard outer covering. During the day they hide under stones, in the crevices of rocks, in the mud, and sometimes in specially constructed burrows along the banks. Since the animal backs into these hiding places, its big claws are ready for business if an enemy attacks it.

Then, too, the colors of crayfishes aid somewhat in protecting them, since these colors are usually similar to the color of the bottoms of the streams in which they live. Lastly, the wide range of vision which the stalked eyes afford must serve to warn the animal of the approach of danger. Nevertheless they do not always escape since crayfishes are often captured by certain birds and fishes. In fact, crayfishes are often used by man as a bait for catching fishes.

EXERCISE 62

The structure and functions of a crayfish. Laboratory study.

A. Regions. The body of the crayfish has two distinct regions. The dorsal surface and sides of the anterior region are covered by a cape, consisting of a single piece of shell-like material. This region is the *cephalothorax* (from the Greek, meaning *head-thorax*). The posterior region is the *abdomen.*

1. Which region is composed of a number of similar segments?
2. Which region has the legs, antennæ (feelers), and eyes attached to it?

B. Adaptations for walking. Place a crayfish in the center of a pan with enough water to cover the animal. If the crayfish does not walk, touch it with the pincers.

1. How many pairs of legs are used in walking?

2. In what directions (forward, backward, or sideways) are you able to get the crayfish to walk?

3. State whether or not the "large claws" are used in walking.

4. Are the walking legs composed of one piece or of several movable parts? Of what advantage is this to the animal?

C. Adaptations for swimming. Place an active crayfish in a pan nearly filled with water. Use the following means to get it to swim: Make a sudden movement toward it with the forceps or pencil; if this does not succeed, take hold of the animal near the anterior end where you can press the large pincers against the body. Do this quickly and release the animal. This action may cause the crayfish to swim in order to escape. If you can not get this crayfish to swim, try another.

1. In what direction does the crayfish swim?

2. State whether or not the legs are used in swimming.

3. Watch the segments of the abdomen and the large appendages at the posterior end to determine their action in swimming.

a. Describe the direction of the movements of these parts.

b. Are these movements made slowly or quickly?

4. In what direction will the doubling under of the abdomen tend to send the animal?

5. In what direction will the straightening out of the abdomen tend to send the animal?

6. In what direction, therefore, must the crayfish strike the harder and quicker in order to swim backwards?

D. Adaptations for breathing.

To the teacher. Prepare some preserved crayfishes in the following manner: Insert the point of the scissors beneath the posterior margin of the cape that covers the cephalothorax and halfway between the middle line of the dorsal surface and the lower margin of the cape; cut forward to the front end of the cape and remove the piece of shell.

1. Immerse in water a crayfish prepared as directed above. Examine and describe the structures that you find above the legs on the side where the cape has been partially removed. These structures are the special breathing organs of the crayfish. They are known as *gills.*

2. Push the gills to one side and find the soft body wall. Higher up find the line of attachment between the shell and the body wall. You will see that the gills are not inside the body, but in a space between the body of the animal and its shell. This space is called the *gill chamber.*

a. In what region of the crayfish are the gill chambers found?

b. What forms the outer wall of each gill chamber? What forms the inner wall?

c. Lift up the cape on the opposite side of the animal; state where it is free from the body wall.

3. Examine the gills on a leg that has been removed from the thorax and floated on water and note that it is largely composed of numerous slender divisions called *gill filaments.*

Make a sketch of the leg (× 2) with the gills attached and label the gill filaments.

4. NOTE (to be copied). The gills are furnished with numerous minute thin-walled blood vessels and the blood in them is separated from the water only by a thin membrane. The blood flows into the gills from all parts of the body by one set of blood vessels and leaves the gills by another.

5. Bearing in mind that breathing is essentially the same in all living things, state:

a. What gas will the blood bring from the body to be given off in the gills in the process of respiration?

b. What gas is taken up by the blood in the gills to be carried around the body?

c. How are the gill filaments fitted by structure to permit this interchange of gases?

d. How are the delicate gill filaments protected from injury?

6. If the same water remained on the gills for some time, what changes in the relative amounts of oxygen and carbon dioxid in the water next to the gills would occur? Why, then, is it necessary that a current of water should pass over the gills?

7. Do currents of water pass through the gill chamber? (Demonstration.)

Inject by means of a pipette some harmless coloring matter, such as powdered carmine in water, into the posterior end of the gill chamber. Place the crayfish again in water.

a. State what is done in this experiment.

b. Give your observations and conclusion.

c. What gas will an incoming current of water bring to the gill filaments?

d. What gas will a current of water carry away from the gill filaments?

8. How the crayfish causes a current of water to pass through the gill chambers.

To the teacher. Prepare several living crayfish so that the action of the gill bailer may be seen. To do this, carefully cut off with scissors a small part of the anterior portion of the shell just over the gill scoop.

Watch the movements of the small bladelike body in front of the gill chamber. This body is the *gill bailer*, or *gill scoop*.

a. Describe the movements of the gill scoop, or gill bailer.

b. When it moves upward and forward, what effect will the gill bailer have on the water in front of it and in the gill chamber?

c. Where can water enter the gill chamber? (See *D*, 2, *c*.)

E. Adaptations for protection.

1. Describe the outer covering of the crayfish. Of what use is this to the animal?

2. Locate the softer parts of the crayfish's armor? How are these protected by their position?

3. Gently touch the eye of a living crayfish. Describe the movements of the eye. How might these movements be advantageous to the animal?

4. Notice the large "feelers" (*antennæ*). What movements do you notice? How might these feelers be advantageous to the animal?

5. Of what use may the large pincers be in addition to helping in securing food? Sketch one of the large pincers complete.

F. Additional drawings.

1. Make out the parts of one of the large antennæ. Notice the broad finlike part at the base of the antenna, then two segments, and a long lash that arises from the second segment. Sketch (× 2) a large antenna. Label.

2. Make a sketch of the dorsal view of the crayfish. Label the regions and all the appendages.

322. Food, food getting, and digestion. At night crayfishes crawl about in search of food, about which they are not at all fastidious, since dead fish and other dead animals seem to be fully as acceptable as when alive. In fact, they are natural scavengers. Crayfish seize their food with their large claws and with the aid of the small pincers on the front walking legs and with the mouth parts, especially the mandibles, reduce the food to pieces small enough to be eaten (Fig. 314). Crayfishes, like the higher animals and man, have a *digestive system*, which is devoted to preparing the food for absorption and use. This system consists of the *alimentary canal* and certain *digestive glands*.

After the food is digested, it can pass into the blood by osmosis and be carried to the cells of the body. When the digested food

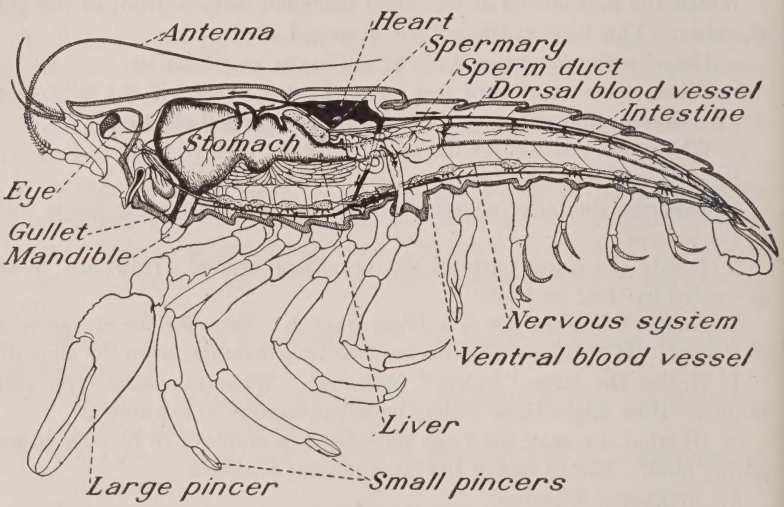


Fig. 314. — Organs of a crayfish

reaches the cells, it may be used by the protoplasm either in making more living matter or, as we shall now see, for the release of energy.

323. Respiration and the production of energy. In our laboratory study we watched the movements of the gill bailer and saw that it caused a current of water to enter the posterior end of the gill chamber and flow over the gills, thus bringing oxygen to the filaments (Fig. 315). The thin-walled blood vessels in the filaments absorb the oxygen, and the blood then passes on into other blood vessels, which carry it back to the heart, whence it is forced all over the body of the crayfish, and so the oxygen in the blood passes into the cells as does the food. Now what becomes of the oxygen within the animal?

As in man and other animals, the oxygen unites with elements in the foods or protoplasm of the cells and produces oxidation

and liberation of energy, which gives the crayfish the power to contract its muscles and so push against the water with its abdomen and tail fin, thus propelling the animal backward, or to open its nippers and shut them and so secure food. In fact, all the work that the crayfish performs is made possible through the oxidation of its foods or protoplasm.

Fig. 315. — Gills of a crayfish

Since the proteins, fats, carbohydrates, and protoplasm all contain carbon, when these are oxidized, carbon dioxid (CO_2) will be formed as one of the waste substances. All these waste substances will pass out of the cells into the blood, which finally conveys them to the filaments of the gills. Here the carbon dioxid passes out into the water, which is then forced out of the front end of the gill chamber.

324. Life history. Crayfishes like other many-celled animals are reproduced by means of special cells known as egg cells which in crayfishes are formed in the body of the female in organs known as ovaries. Before they can develop, however, these egg cells must be fertilized by sperm cells, produced in spermaries of the crayfish (Fig. 314). After extrusion, eggs are fertilized and by a sticky substance are attached to small appendages, or *swimmerets*, on the ventral surface of the abdomen of the female. Here the fertilized egg cell develops into a many-celled embryo, and finally a tiny crayfish hatches. At first the young crayfishes are held to the swimmerets by threads; later they cling by means of their pincers, and after some days become independent. At intervals in both young and old crayfishes, the hard outer covering of the body is shed. This shedding of the skin is called *molting*. Without this process it would be impossible for the young to grow.

While the young crayfishes are attached to the parent, they are of course protected by their position, and the female looks after them by looking out for herself. The food for the developing

embryo is stored in the egg. After hatching, the young must care for themselves, and after they become independent they receive no protection at all. There is, therefore, in the case of crayfishes nothing like the parental care of higher animals.

325. Relatives of the crayfish. One of the relatives of the crayfish is the lobster, which is a salt-water animal found along the North Atlantic coast. Like that of the crayfish, its body consists of a cephalothorax and a clearly segmented abdomen. The lobster also has two pairs of antennæ, a pair of stalked eyes, a number of pairs of mouth parts, a pair of big claws, four pairs of walking legs, to the bases of which gills are attached, and a pair of swimmerets on each of the segments of the abdomen except the last. In general, lobsters are very much larger than crayfishes, one of the largest known specimens weighing over twenty-three pounds.

Less like the crayfish in appearance are the crabs, yet a careful examination shows that these animals have practically all of the characteristics mentioned in the preceding paragraph. The cephalothorax of crabs, however, is usually wider than it is long, and the abdomen is much reduced and is commonly folded in a groove beneath the cephalothorax. Few of the crabs are able to swim; usually they crawl sideways by the help of their four pairs of walking legs.

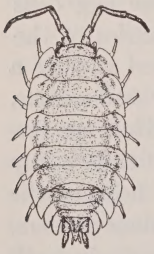


Fig. 316.— Sow bug

"A curious modification of habit is shown in the hermit crab, which in early life backs into an empty snail shell which aids in protecting it from its enemies. The abdomen, thus covered, becomes soft and flabby. As growth proceeds the necessity arises for a larger shell, and the crab goes 'house-hunting' among the empty shells along the shore, or it may forcibly extract the snail or other hermit from the home which strikes its fancy." [1]

Among the relatives of the crayfish that live in damp places on land are the pill bug and the sow bug (Fig. 316) which are often found beneath water-soaked wood. All the animals we have

[1] Jordan and Heath's *Animal Forms*

described in this chapter belong to the group of crustaceans, so called from the hard outer shell which invests them.

326. Economic importance of the crustaceans. Crayfishes are highly esteemed as food in Europe, particularly in France, and special efforts are made to increase their number. In this country, however, they have, as yet, been used but little as food. Their principal use is for bait in catching certain kinds of fish.

The lobster is to us what the crayfish is to Europeans. While they are not abundant enough to be considered a very important source of food, still the fishermen in 1901 received $1,400,000 for the lobsters caught. They are considered rather as a delicacy, since they are too expensive for general use, principally on account of their scarcity. For a number of years the United States Government has been making efforts to increase the number of lobsters by artificial propagation. Some states have passed laws forbidding the catching of immature lobsters and lobsters with eggs attached.

Fig. 317. — Shrimp

Other crustaceans that are used for food are prawns, shrimps (Fig. 317), and certain kinds of crabs. Nearly all the crustaceans eat dead animal food; consequently they are useful in keeping the water free from dead material.

CHAPTER XXIV

FROGS AND THEIR RELATIVES

327. Habits of frogs. There are many kinds of frogs, differing from one another considerably in size and color; but all frogs live in places where water is more or less abundant. Frogs are often found either on the banks of ponds (Fig. 318) and streams or floating on the surface of the water with only the tip of the nose above water. In color they usually resemble their surroundings rather closely and so secure a certain degree of protection from fishes, snakes, birds, and man, which are their more common enemies. When pursued, they quickly disappear beneath the water and often bury themselves in the mud at the bottom until the need of air compels them to return to the surface. Late in the autumn they burrow in the mud and remain there until the following spring. The more or less pointed snout of the frog, its slippery skin, its long, muscular legs, and its webbed feet all adapt the animal for rapid swimming through the water.

EXERCISE 63

Structure and functions of a frog. Laboratory study.

A. Regions and appendages.

1. NOTE (to be copied). The frog's body consists of two principal parts, or regions; namely, the *head* and *trunk*. The line of union between the two regions is just in front of the anterior appendages (arms).

2. Locate the appendages (*arms* and *legs*) attached to the trunk.

3. Name and locate the organs that you find on the head, giving the number of each.

B. Breathing organs.

1. Describe the location of the nostrils on the head.

2. Examine a preserved specimen in which a stiff bristle has been passed through one of the nostrils.

a. Tell what was done.

b. Into what cavity has the bristle emerged?

c. In what region (anterior or posterior) of the roof of the mouth cavity are the inner openings of the nostrils located?

3. (Demonstration by teacher.) Just back of the tongue there is

Courtesy American Museum of Natural History

Fig. 318. — Habitat of frogs

Four frogs may be found in the picture. A black snake (center) is preparing to devour one of the frogs.

a narrow opening that leads into the windpipe (*trachea*). This opening is called the *glottis*.

a. Locate the glottis.

b. Does the glottis extend lengthwise or crosswise of the mouth cavity?

c. Into what does the glottis open?

4. Examine a fresh dissected frog prepared in such a way as to show the lungs.

a. State the location of the lungs with reference to the head and the cavity of the trunk.

b. Describe the appearance of the lungs.

c. Insert the end of a glass tube, drawn out to a small diameter, into the glottis opening and blow air into the lungs. Describe what you have done and state the result.

5. Name in order the openings, the cavity, and the tube through which the air must pass in order to reach the lungs.

C. Breathing movements.

1. Place a frog in a glass jar with an inch or two of water and watch the action of the floor of the mouth. This is one of the breathing movements. Describe this breathing movement of the frog.

2. There are two breathing movements of the sides of the trunk: one a very active inward and outward movement and the other a very slight inward and outward movement. When you have seen these two kinds of movements of the sides, describe them and state which kind occurs the more frequently.

D. How the frog exhales.

1. What effect will the active inward movement of the sides have upon:

a. The size of the body cavity?

b. The size of the lungs?

c. The pressure of the air in the lungs?

2. When the sides of the trunk move actively inward, will the air move into the lungs or out? Why?

3. Through what passages will the air go from the lungs to the outside of the frog?

E. How the frog inhales.

1. When the floor of the mouth moves downward —

a. Will the size of the mouth cavity be made larger or smaller?

b. If the nostrils are now open will the air move into the mouth cavity or out? Why?

2. When the floor of the mouth is raised —

a. Will the size of the mouth cavity be increased or decreased?

b. Will the pressure of the air in the mouth cavity be increased or decreased?

c. If both the nostrils and the glottis are now open, in what directions will air be forced?

d. What causes the slight outward movements of the sides of the trunk in the region of the lungs?

F. How the lungs are fitted for breathing organs. (Suggested as home work.)

1. NOTE (to be copied). When the lungs are inflated (see *B*, 4) they look like bags (Fig. 321). The lungs are hollow, and their walls are composed of thin material. In these membranous walls are thin-walled blood vessels known as *capillaries*. The heart forces blood that has come from the body into these capillaries of the lungs and then back to the heart.

2. Bearing in mind that respiration in all living things is essentially the same, state:

a. What waste substance the blood brings to the lungs to be given off from the capillaries.

b. What gas the blood in the capillaries takes up from the air in the lungs.

c. How the walls of the lungs and of the capillaries of the lungs are fitted by structure to make this interchange of gases possible.

G. Some adaptations for food getting.

To the teacher. Select a number of preserved or freshly killed frogs of as large a size as you can get. Open the jaws as far as possible and keep them in this position by means of small pieces of wood.

1. Seize the posterior or hind end of the tongue and pull it forward.

a. Tell what you have done and state which end of the tongue is attached to the floor of the mouth.

b. Describe the shape of the free end of the tongue.

2. The living frog can extend its tongue much farther than you have been able to do in the case of the preserved frog, and in the living frog the tongue is covered with a very sticky substance. The tongue is used to catch insects at some distance from the animal (Fig. 320). Tell how you think the frog could use its tongue to catch insects and get them into its mouth.[1]

3. Look for teeth on the jaws of a skeleton of a frog; or if you can not obtain a skeleton, rub the finger over the jaws of a preserved specimen.

a. Which of the jaws has teeth?

[1] If possible live frogs should be fed on meal worms, or other insects, and the feeding movements observed.

b. Describe the location of the teeth on the jaw.
c. State the shape and size of the *jaw teeth.*
d. What is the probable use of the jaw teeth?

4. Look on the roof of the mouth for two relatively large *palate teeth.* Rub the fingers over the surface of the palate teeth.

a. Tell what you have done.
b. What have you found out about the palate teeth?
c. What is the probable use of the palate teeth?

H. How a frog swallows.

1. Gently touch the eyes of a living frog until it draws them into the head. Tell what you have done and observed.
2. Look at the roof of the mouth of a preserved specimen while you push the eyes into the head. Tell what you have done and describe the effect produced in the roof of the mouth.
3. How will the act of pulling the eyes into the mouth cavity be useful to a frog in swallowing? [1]

I. Structure of arms and legs. Place a frog in a glass jar at least half full of water to cause the animal to extend the hind legs.

1. Make a sketch (natural size) of an arm to show the shape and size of the following parts: upper arm, elbow, forearm, hand, number of fingers. Label each part.
2. Draw one of the legs (natural size) to show the following parts: thigh (next the body), knee, shank, ankle (elongated region above foot), foot, toes, web between toes. Label each part.

J. How a frog swims. Place an active frog in a sink or other receptacle large enough to afford it room to swim. The water should be deep enough so that the frog will not strike the bottom with the legs. Get the frog to swim the full length of the receptacle as many times as may be necessary to answer the following:

1. Tell what you have done.
2. Describe the movements of the hind legs in swimming.
3. In which of these movements are the toes spread out?
4. In which of these movements, therefore, can the frog get the best hold upon the water?

[1] See footnote on the preceding page.

5. In which direction must the frog push the harder in order to move in the direction that it does?

6. In what respects are the posterior appendages well fitted for swimming?

7. In what respects are the anterior appendages not so well fitted as the legs for swimming?

K. How a frog jumps. Place a frog where there is plenty of room, and get it to jump as many times as necessary to answer the following:

1. Tell what you have done.

2. Describe the position of the parts of the legs just before the frog jumps.

3. Describe the movements made by the parts of the leg in the act of jumping and in the act of landing.

4. In which of these two movements must the frog use the greater force?

5. Which movement, therefore, throws the frog into the air?

6. In what respects are the legs better adapted for jumping than the arms?

L. Internal organs.

To the teacher. Put into a covered jar enough frogs to supply each two students with a specimen. Put into the jar some ether, or, better, saturate a small sponge with the ether and place it in the jar. When the animals are dead, dissect them as follows: Lift up the skin of the ventral wall of the abdomen with the forceps; carefully insert the point of the scissors near the posterior end of the trunk, and carefully cut forward on one side of the body as far as the tip of the head and back on the other side of the trunk, until the skin is completely removed from the ventral surface. In a similar manner remove the muscular wall that covers the trunk, being careful not to injure the internal organs. If time allows, remove also the skin from one leg; call attention to the thinness of the skin and to the underlying blood vessels; show the characteristics and action of the leg muscles.

If the specimen is a female, remove nearly all the eggs and throw them away. Insert a blowpipe in the glottis and partly inflate the lungs. Wash the specimens thoroughly to remove all traces of blood and cover them with water in a dissecting pan.

If the specimens are needed on successive days, they should be wrapped in a wet cloth immediately after the class work of each day and kept in a cold place. Use only specimens that are fresh.

1. Make an outline drawing (natural size or twice natural size if the frogs are small) of the ventral view of the head and trunk regions of a dissected specimen, together with the base of each of the four appendages, and *draw nothing else until directed to do so.*

2. The *heart* is a cone-shaped body midway between the arms. Draw the heart to show its position, shape, and relative size.

3. On either side of the heart are the *lungs*. Stretch one of them a little by pulling on it; then letting it go.

a. State whether or not the lungs are elastic. Are they hollow or solid?

b. What is the color of the lungs? State whether or not you find tiny blood vessels in the fresh lung.

c. Draw the lungs so as to show their situation, size, and shape.

4. On the frog's right side and behind the heart and lungs is the reddish, several-lobed *liver*. Sketch in your drawing the liver to show it in position.

5. On the frog's left side and under the liver in its natural position is a whitish, oblong body, which narrows at its hinder end. This body is the *stomach*. Push the handle of the dissecting needle down the gullet into the stomach.

a. Tell what you have just done.

b. What organ does the handle enter?

c. Draw it in its natural position to show its shape and size.

6. Extending from the stomach is a tubular structure of considerable length, the *small intestine*. At the lower end of the small intestine the tube becomes larger and then disappears between the two thighs. This last part of the tube is called the *cloaca*, or *large intestine*. Draw the small and large intestines as seen in position.

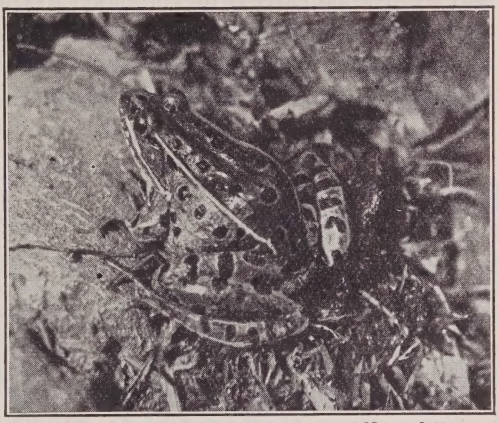
7. Between the stomach and the first loop of the small intestine is a thin pink body, the *pancreas*, which is a very important digestive gland. Make a separate drawing of the stomach and the loop of the intestine to show the pancreas.

8. Label heart, lungs, liver, stomach, small intestine, large intestine, bile sac, pancreas.

9. Find two red bodies on either side of the spinal column. These bodies are the *kidneys*. The kidneys remove the *nitrogenous waste* (*urea*) from the blood. If the specimen is a male, note the orange-colored spermaries. If it is a female, note the position, appearance, and number of the eggs in the ovaries. Make a separate sketch of the kidneys and spermaries or ovaries twice the natural size.

10. Dissect out the whole alimentary canal, carefully cutting the membranes that hold together the coils of the intestine. Float the alimentary canal in a tray of water. Lay the liver over to one side and

find between the lobes on the under side a thin-walled, green sac, the *bile sac* (or *gall bladder*). Draw all of these parts and label the gullet, stomach, small intestine, large intestine, lobes of the liver, gall bladder, and pancreas.



Courtesy American Museum of Natural History

Fig. 319. — Frog seeking food

328. How frogs are adapted for food-getting and digestion. Frogs feed upon insects, fish, and other frogs, and even birds have been found in their stomachs. Insects are caught by the aid of the slimy tongue, the tip of which can be quickly thrust out of the mouth and then drawn back again with the insect adhering to it (Fig. 320). The tiny teeth that are found on the upper jaw and the two large teeth in the roof of the mouth are useful only in preventing the escape of the prey from the mouth. Hence the food is swallowed without being chewed, and after passing down the short gullet it enters the tubular stomach (Fig. 321), where it is partially digested by ferments secreted by certain cells found in the lining of this organ.

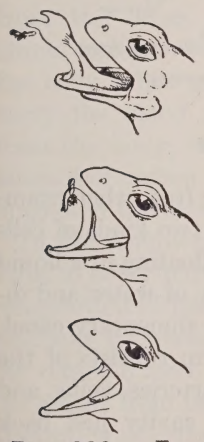


Fig. 320. — Frog catching an insect

When the food leaves the stomach, it enters the coiled small intestine where the process of digestion is continued by the bile secreted in the liver and the pancreatic juice prepared in the pancreas.[1] As the digested food slowly moves along the small intestine, it is absorbed by the capillaries

[1] Both of these digestive fluids are carried to the intestine by ducts.

(thin-walled blood tubes) in the mucous membrane of this tube and so may be carried by the blood to the various cells of which the body is composed. Digestion not only prepares the food for absorption but makes it ready to be used in the cells either for growth and repair or for the production of energy.

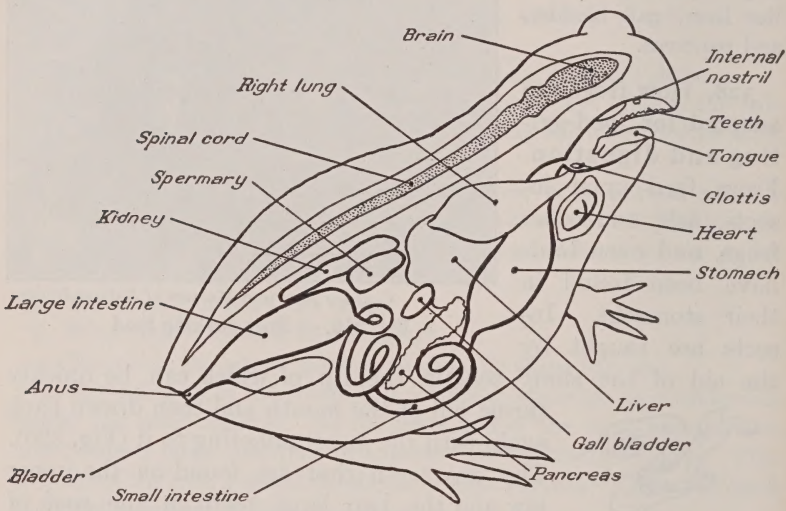


Fig. 321. — Internal organs of a frog

329. Blood and circulation. The blood of the frog, when examined under the microscope, is seen to consist of two kinds of cells (*red* and *white corpuscles*) (Fig. 322) which are floating in a liquid known as *plasma*. The plasma consists largely of water and digested foods that have been absorbed from the alimentary canal.

As in the human body, the circulatory system consists of the heart and three kinds of blood vessels; namely, arteries, veins, and capillaries. The heart is located in the body cavity just back of the head and consists of two auricles and a ventricle (Fig. 323), instead of a single auricle and ventricle as in the fish (Fig. 222). As might be expected, this makes necessary other differences in the circulatory system of the frog. In the fish we have found that

there is only one stream of blood flowing into the heart, while in the frog there are two. One stream enters the heart from the various organs of the body which the blood has supplied with food and oxygen and from which the blood has received carbon dioxid. The second blood stream comes from the lungs where the blood has given off the carbon dioxid and received a fresh supply of oxygen. The right auricle receives the blood brought from the body in three large veins, while two small veins carry into the left auricle the blood from the lungs.

The blood from both auricles now flows into the single ventricle, which then contracts and pumps the blood into a large artery. Certain branches carry the blood having the larger amounts of oxygen (*i.e.* the blood from the lungs) to the head, trunk, legs, and other organs of the body, while other branches carry the blood just received from the body, with its larger amount of carbon dioxid, to the lungs and the skin.

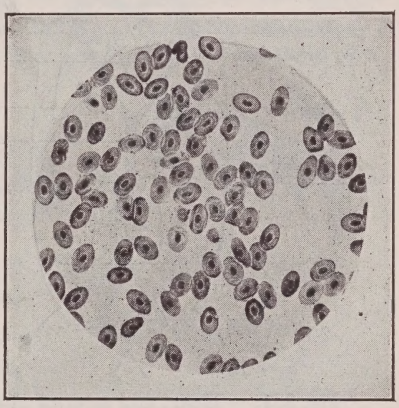


Fig. 322. — Corpuscles of frog's blood

Magnified about 50 times. Photographed through a microscope. The oval disks, are the red corpuscles, each with a nucleus.

In the thin-walled capillaries which connect the arteries and veins in every part of the body (Fig. 324) all the changes in the composition of the blood take place. The capillaries outside the mucuous membrane of the stomach and the intestines absorb the digested food. The capillaries in the muscle tissues permit the escape from the blood of oxygen and food substances and the absorption of carbon dioxid and other wastes.

[1] A tadpole's tail is excellent for demonstrating the blood current. Wrap a tadpole in wet cloth or cotton and support it so that the tail can be placed between two glass slides on the stage of the microscope. The space between the two sides should be kept filled with water. The movement of the corpuscles through the margin of the tail should be examined with the low power of the microscope.

330. Respiration and the liberation of energy. The walls of the frog's lungs contain a network of capillaries, and in these thin-walled tubes the red corpuscles absorb the oxygen that is forced into these sacs by the upward movement of the floor of the mouth. As we have seen, the blood with a fresh supply of oxygen flows from the capillaries of the lungs into the veins and so finally into the left auricle and thence into the ventricle. Here it tends to become somewhat mixed with the blood from the right auricle which has just returned from the body. However, the structure of the heart and the arteries is such that the blood that has come from the lungs with a larger supply of oxygen is sent out by arteries to all parts of the body.

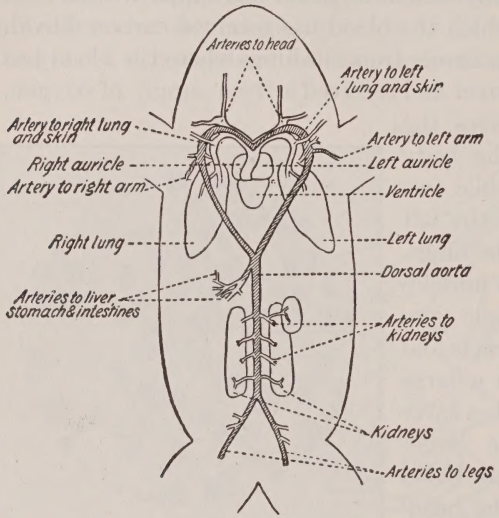


Fig. 323. — Heart and arteries of a frog

In the capillaries the oxygen is absorbed by the cells. Oxidation of the food and protoplasm takes place, and energy is thereby released, which enables the frog to accomplish locomotion, secure its food, and perform all its destined tasks. The carbon dioxid and other wastes produced by oxidation pass through the capillary walls into the blood and, as we have seen, are carried back to the heart and then

Fig. 324. — Capillaries in the web of a frog's foot
Note the red corpuscles in the capillaries.

to the lungs, where carbon dioxid is excreted. Other wastes are excreted by the kidneys.

The skin of the frog is likewise permeated by a network of capillaries so that it acts as do the gills of fishes in absorbing oxygen from the water and in giving off carbon dioxid. While the frog is buried in the mud during the winter, it breathes entirely through the skin. So much does the frog depend on the skin as a breathing organ that even in summer, if the skin becomes dry so that air can not be absorbed, the frog dies.

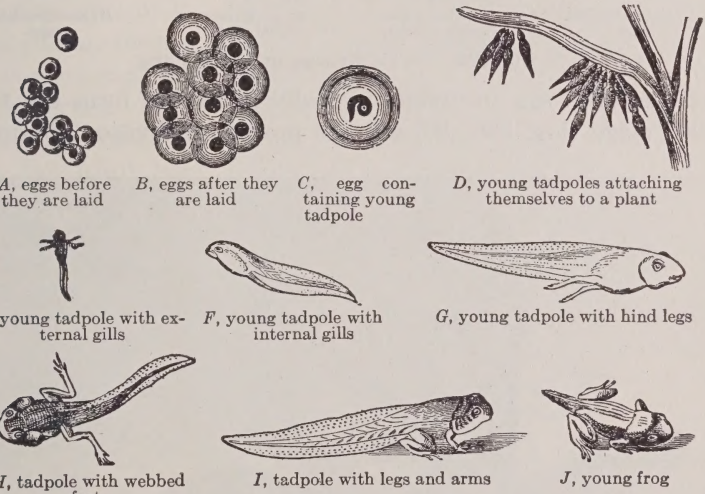

A, eggs before they are laid
B, eggs after they are laid
C, egg containing young tadpole
D, young tadpoles attaching themselves to a plant
E, young tadpole with external gills
F, young tadpole with internal gills
G, young tadpole with hind legs
H, tadpole with webbed feet
I, tadpole with legs and arms
J, young frog

Fig. 325. — Life history of a frog

331. Reproduction and life history. In the animals studied thus far we have found special organs devoted to the process of reproduction; namely, ovaries for egg production in the female and in the male spermaries that form the sperm cells. Before the egg cells can develop into embryos, each must be fertilized by a sperm cell. All the facts we have just stated apply equally well to the frog.

Frogs' eggs are deposited in springtime in masses that float on the surface of the water [1] (Fig. 325, *B*). Each fertilized egg is a

[1] If possible eggs in different stages of segmentation should be secured, preserved in 5 per cent formalin, and used for demonstration.

small sphere, black on its upper surface and white beneath and inclosed in a gelatinous covering. The warmth of the sun causes

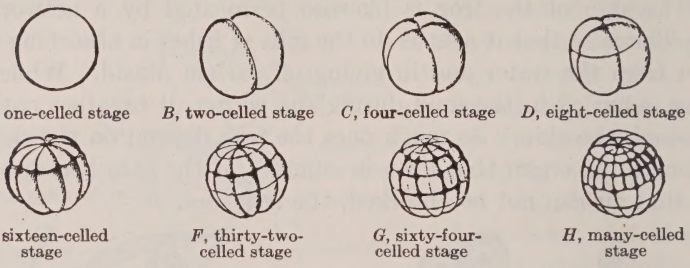
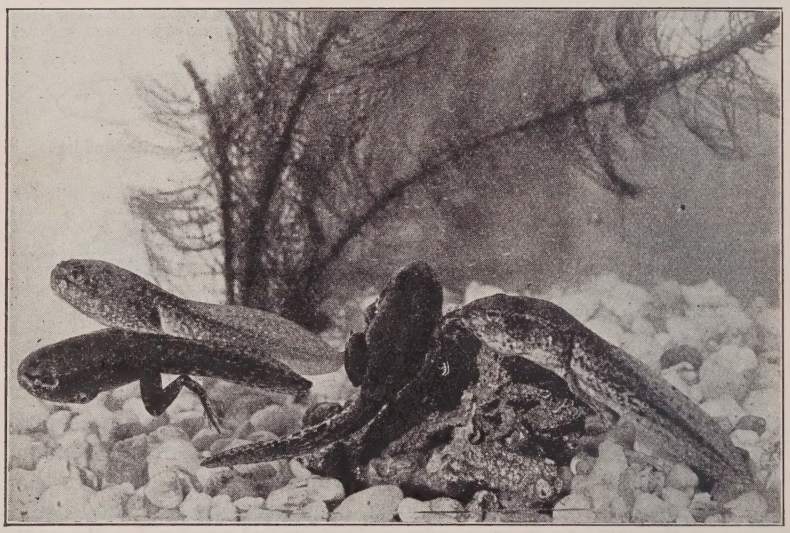


Fig. 326. — Cell division in a frog's egg

the one-celled egg to divide vertically in half to form the two-celled stage (Fig. 326, *B*), and the process of division continues



Courtesy N. Y. Zoological Society

Fig. 327. — Tadpoles

These animals were photographed in an aquarium.

until the egg consists of many cells (Fig. 326, *H*). Food for the development of the embryo is stored in the egg.

The many cells of the egg gradually become different in character and so form the various organs of the embryo (Fig. 325, *C*). Soon after hatching, the young of the frog, known as *tadpoles*, secure their food by sucking in tiny water plants found on the surface of plants and stones (Fig. 325, *D*). Tadpoles resemble fishes in having gills for breathing, a heart with two chambers instead of three, and a tail for locomotion. At first the gills are on the outside of the body (Fig. 325, *E*), but later four pairs of internal gills are formed, and the external gills are absorbed. The animal increases in size, the hind legs appear (Fig. 327), and the arms are formed beneath the skin. Meanwhile the lungs are being developed, the heart becomes three chambered, the legs grow larger, arms appear, and finally the gills and the tail are completely absorbed. The tadpole now leaves the water, since it is an air-breathing animal. This succession of changes after hatching from the egg is known as a *metamorphosis*.

Courtesy American Museum of Natural History

Fig. 328. — Toad

332. Relatives of the frog. Much like the frog in structure and life history is the common garden toad. Toads, however, in their adult stage cover themselves more or less with dirt in the daytime and come out at night to feed upon insects, which constitute their sole food. Instead of having a smooth, slimy skin, as does the frog, a toad's skin (Fig. 328) is dry and covered with elevations commonly known as "warts." These elevations contain cells which secrete an irritating substance that protects the toad from animals that would prey upon it. There is no foundation, how-

ever, for the popular notion that the warts of human beings are ever caused either by toads or frogs.

In springtime toads seek the water in which to breed. The eggs, covered with a gelatinous substance, are laid in long strings instead of in masses, as is the case with frogs. The development and life history of the toad is much the same as that of the frog. As soon as metamorphosis is complete, the little toads leave the

Courtesy American Museum of Natural History

Fig. 329. — Spotted Salamander

water and often are found considerable distances away from water.

Less like the frog, at least in the adult stage, are the salamanders (Fig. 329) and newts. These are found in damp places or in water and are often called "lizards," by those who do not know that a lizard has scales, claws on its feet, and breathes throughout its life by means of lungs. Some of the relatives of the frog, even after they have developed lungs, retain gills throughout their life (Fig. 330).

Because of the ability of the animals described in this chapter to live both on the land and in the water, they are called Amphibia (from the Greek, meaning *both lives*).

333. Economic importance of the amphibians. None of the amphibians, so far as is known, is harmful to man. On the contrary, all of them are more or less useful because of the insects

Fig. 330. — Full-grown amphibian (Necturus)
This relative of the frog retains its gills even when fully developed.

they devour. This is especially true of the garden toad. It has been estimated by one author that a toad in a garden is worth nearly twenty dollars a year on account of the cutworms and other injurious insects that it destroys. In France the gardeners even buy toads to aid them in keeping obnoxious insects under control. Frogs, in addition to their value as insect destroyers, are of some value to man as food. Frogs are also used as fish bait.

CHAPTER XXV

HOW PROTECTION AND LOCOMOTION ARE SECURED BY LIVING THINGS

I. How the Skin and Other Outer Coverings Are Useful to Living Things

334. What functions of living organisms, other than those of nutrition and reproduction, are necessary. The life of every organism is subjected to dangers that constantly threaten its existence. Thus, for instance, a tree may be exposed to severe winds that threaten to uproot it, to lightning that would rend it asunder, to drought that would deprive it of moisture, to floods that might overwhelm it, to insects and fungi that might sap its life, and to other trees that might interfere with its supply of sunlight and soil water. Animals and human beings are likewise subjected to similar and to other dangers which may arise in the environment of living and lifeless things.

What, then, must a plant, an animal, or a human being do in order to reach maturity and perpetuate its kind? Evidently it must develop means of protection against those parts of its environment that endanger its existence. Let us consider some of the adaptations that living things have developed in the course of life which serve as a means of protection.

335. How outer coverings of plants serve as a means of protection. In plants, even when young, we find a somewhat resistant outer layer, known as the *epidermis* (Figs. 81, 91). As a plant grows older, the protecting outer layers become thicker and tougher. In trees this covering, known as bark, may become very thick indeed and so may help to prevent mechanical injuries and attacks by insects and parasites. Some plants, such as the hawthorn, rose bush, and thistle, have additional outer protection

in the form of thorns and prickers. The various outer layers likewise protect the plant from excessive loss of moisture and, perhaps, from sudden temperature changes.

336. How the outer coverings of animals serve as a means of protection. In the animal kingdom what a wide range of protective devices is evident! Lobsters, crabs, and insects, for example, are each incased in a heavy shell. Snails, oysters, and clams have developed limestone shells of varying thickness that may completely envelop them. Most of our common fishes and snakes and lizards, in addition to a tough skin, have hard scales that overlap each other in much the same way as the shingles on a house. One of the most perfect means of protection is the shell of the turtle. This is a box, composed of horny and bony substance, with openings at the ends into which the animal can withdraw head, legs, and tail (Fig. 133).

In the birds, special protective structures, the feathers (Fig. 267), have been developed, while the mammals, the highest group of animals, are covered with hair. Both hair and feathers serve mainly as a protection from loss of heat, whereas the hard outer coverings of the other animals mentioned serve to a considerable extent as protection against their animal enemies.

It seems reasonable to suppose that the ability of many forms of animal life to escape their enemies is due to the fact that in color or general appearance they so closely resemble their surroundings as to be well-nigh indistinguishable. Some of the most striking examples exist among the insects. Among this group of animals we may name the green caterpillars and katydids resting on the green parts of plants, walking sticks at rest on brown twigs, and moths on the bark of trees having a similar color. Of the higher forms we may mention the brown rabbit or nighthawk crouching motionless close to the ground (Fig. 331), the white polar bears and white foxes against their snowy background, and the rattlesnake and the horned toad closely resembling the sands of the desert.

337. What the characteristics of the skin of man are. The whole outer surface of our bodies is incased in a flexible, elastic

skin of varying thickness and texture. In regions like the palm of the hand and the sole of the foot, for instance, the skin is thick and tough, while the covering of the lips is extremely thin. At the ends of the fingers and toes are the nails, and all parts of the body, with the exception of the palms of the hands and the soles

Courtesy National Audubon Society

Fig. 331. — Nighthawk brooding young

Note the protective resemblance between the bird and its surroundings.

of the feet, are covered with hair, which varies both in length and density. Both the hair and the nails are modified parts of the skin.

What the functions of the skin are. The most obvious use of the skin is the protection it affords for the muscles and other organs that lie beneath. In the second place, it has a countless

number of sense organs which receive messages from the outside of the body. These messages are hurried in along nerve fibers to the spinal cord and brain; and in this way we then get impressions of temperature, of pressure, and of pain. Again, by means of the perspiratory action of the skin, the body throws off a great deal of water and small quantities of other waste matters. And, finally, as a result of the evaporation of this water from its outer surface, the body loses its surplus of heat and so keeps an even temperature of about 98° F.

338. What the characteristics of the layers of the skin are. The skin everywhere consists of two distinct layers: an outer, called the *epidermis* (from the Greek, meaning *outside skin*) and an inner, the *dermis* (Fig. 332). When one gets a blister by burning the skin, most of the epidermis is lifted up by an excessive amount of lymph that comes out of the blood capillaries and lymph vessels. In a blister one can easily distinguish the white epidermis from the pink layers of the dermis lying beneath.

Let one wash with soap and water the surface of a portion of one's body and then rub it vigorously. One will find that thin layers of the outer skin are easily removed and rolled into tiny cylinders. If a needle be inserted into the skin that covers a blister, the touch of the needle will be felt, but no pain is caused, nor does the blood flow. By means of these simple experiments we learn the following facts in regard to the epidermis: (1) the outermost layers are being constantly worn away, and hence we infer there must be a constant growth from beneath to supply this loss; (2) blood vessels are lacking in the outer skin; and (3) nerve fibers are present in the epidermis, for we are conscious when the covering of a blister is touched.

In the dermis and beneath the skin are found the blood vessels, most of the nerves, and the sweat and the oil glands (Fig. 332).

339. How the skin, kidneys, and lungs coöperate. The kidneys are organs of first importance in ridding the blood of its wastes (Fig. 109). If they stop work altogether, death occurs in twenty-four to forty-eight hours. Fortunately the skin can help to a certain extent by excreting an abnormal amount of urea and salts.

Under ordinary conditions about three pints of urine should be given off by the kidneys of an adult in twenty-four hours. This amount is lessened if perspiration is extensive. Almost all the carbon dioxid formed in oxidation is given off from the lungs, very little being excreted by the kidneys and skin. Water is given off by all three organs; urea from two (kidneys and skin).

340. Why bathing is important. The oil (sebaceous) and perspiratory glands (Fig. 332) are constantly pouring their secretions in greater or less quantity upon the skin. As the water evaporates, the oil and the solid ingredients of the sweat are left behind. Unless these are removed, they tend to clog the openings of the ducts from the glands and so interfere with the work of the skin. A considerable amount of these substances is doubtless worn away, together with the scales of the outer skin, by friction against the clothing. But if the skin is to carry on its functions to the best advantage, frequent baths must be taken.

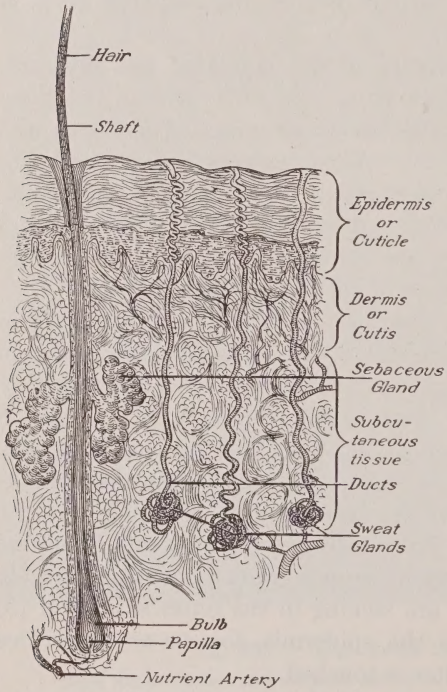


Fig. 332. — Section of the skin
This is highly magnified.

341. Kinds of baths. The oily secretions and much of the accumulated dirt on exposed surfaces of the skin can be removed only by the use of warm water and soap; hence these should be employed upon the hands two or three times a day and at least once or twice a week upon the whole body. *Warm baths* should

be employed, however, for their cleansing effect only, since they are usually followed by a feeling of lassitude. One is much more likely to catch cold, too, after exposure to warm water, as it opens the pores of the skin, causes the arteries near the surface to dilate, and thus increases the amount of perspiration. Unless the warm bath is taken just before one goes to bed, it should be followed by a quick application of cold water.

Cold baths, on the other hand, if taken under proper conditions, have an exhilarating effect. The best time for such a bath is immediately after one rises in the morning. Until one becomes accustomed to the cold temperature, the water may be applied with a sponge. The body should then be rubbed vigorously with a towel. In our study of the circulation we referred to the effect of heat and cold upon the arteries. After their first contraction caused by the contact of the cold water with the skin, the blood vessels enlarge, and one feels all over the body a warm, healthful glow. Cold baths should never be taken immediately after one eats, since the blood is thereby drawn away from the organs of digestion. Nor should one remain in cold water until one feels a chill. If the warm reaction does not take place after the bath, the latter is not beneficial, but injurious. Cold baths are undoubtedly one of the best means of protecting the body against colds. *Shower baths*, however, are better than a cold plunge, for they stimulate both by the cool temperature of the water and by the force with which it strikes the skin.

342. How the hair should be cared for. The oil glands are most numerous in the scalp; and if the skin is in a healthy condition, the hair is supplied with just the proper amount of oil. If this secretion dries, however, and becomes mixed with the loose outer scales of the epidermis, *dandruff* is caused, and this should be removed by vigorous brushing and shampooing. Not only is the scalp cleaned in both of these ways (if clean brushes and combs are used), but the friction stimulates the circulation of the blood through the scalp, and good blood is a better hair tonic than any external application. If the oil supply is insufficient and the hair becomes dry, liquid vaseline may be used. The

scalp should be well dried after a bath, for moisture at the roots of the hair tends to cause decomposition on the scalp.

343. How the nails should be cared for. One of the surest means of detecting slovenly personal habits is by observing the care an individual takes of his finger nails. An accumulation of dirt beneath the nails or jagged edges caused by one's biting the nails almost always indicate a want of good breeding. The finger nails should be carefully cleaned with soap, water, and a nail brush or with a nail cleaner, but never with a penknife or scissors, for metal roughens the surface and thus makes places for the lodgment of dirt. The most convenient method of trimming the nails is in a curved direction, and this gives them the best appearance. It is better to trim the nails with a file than to cut them. The roll of epidermis about the base of the nail should frequently be pushed back after the hands have been soaked in soap and water; otherwise this outer skin is likely to become torn and to form the so-called "hangnails." These are often a source of great discomfort and sometimes of danger, for they furnish a possible opening for infection by bacteria.

344. How burns should be treated. We have already suggested the treatment for cuts and bruises of the skin in connection with the blood system (**147**) and bacteria (**202**). Another form of accident that may injure the skin is a burn. The affected part should be covered with a paste of baking soda, which tends to lessen the pain by keeping out the air and by reducing the inflammation. A mixture of equal parts of linseed oil and limewater (known as *carron oil*) is also a good remedy to keep on hand for burns. If the clothing of a person catches fire, the flames should be extinguished by wrapping him quickly in thick clothing or rugs.

345. How the heat of the body is regulated. The temperature of the healthy adult human body as a rule is 98.6° F. This does not vary to any appreciable extent in winter or summer, no matter how vigorously one may exercise. Yet during exertion oxidation goes on much more rapidly, and a great deal of heat is thereby released. What then becomes of this extra heat?

In fevers the temperature sometimes runs up to 105° or more. At this time we know that the skin is dry and parched, for the body is unable to perspire. We may infer, then, that *in health we keep cool by perspiring,* and such proves to be the case. During exercise the heart beats with greater rapidity, and the heated blood is driven more rapidly through the skin as well as through other organs of the body. When it comes in contact with the two and a half million sweat glands of the skin, a great deal of water is given out, and this soon reaches the surface and collects in drops. In evaporating this water the body loses its surplus of heat, since the heat absorbed by this water while evaporating is taken from the body. When sufficient heat has been lost, perspiration practically ceases. By this automatic process our bodies keep at an even temperature, whatever may be the condition of the air or the degree of oxidation within us. Dogs can not cool off by sweating, since they have no sweat glands in the skin; instead they pant and extend their tongues to cool themselves.

346. What the effect of alcohol is on body temperature. "The action of alcohol in *lowering the temperature,* even in moderate doses, is most important. By dilating the cutaneous vessels, it thus permits of the radiating of much heat from the blood. When the action is pushed too far, and especially when this is combined with the action of great cold, its use is to be condemned." [1]

"A party of engineers were surveying in the Sierra Nevadas. They camped at a great height above the sea level where the air was very cold, and they were chilled and uncomfortable. Some of them drank a little whisky, and felt less uncomfortable; some of them drank a lot of whisky and went to bed feeling very jolly and comfortable indeed. But in the morning the men who had not taken any whisky got up in a good condition; those who had taken a little whisky got up feeling very miserable; the men who had taken a lot of whisky did not get up at all: they were simply frozen to death. They had warmed the surface of their bodies at the expense of their internal organs." [2]

[1] Landois and Stirling in *Textbook of Human Physiology.*
[2] T. Lauder Brunton in *Lectures on the Action of Medicine.*

II. How Skeletons Are Useful to Living Things

347. What kinds of skeletons there are. In the animal kingdom we find two kinds of skeletons. In the first place, many animals, like the clam, oyster, crayfish (Fig. 314), lobster, and insects, have their skeletons on the outside of the body. This type of skeleton is known as an *exoskeleton* and is the only kind of skeleton possessed by animals that are known as *invertebrates*, that is, animals lacking a "backbone." Exoskeletons, however, are not confined to the invertebrates. Indeed, most animals having a backbone are also provided with an exoskeleton in the form of a skin, which is reinforced oftentimes with special structures, such as scales, hair, feathers, and nails.

A second kind of skeleton is present in the vertebrate group of animals only; namely, an inside skeleton, or *endoskeleton*. Since the axis of such a skeleton usually consists of a series of bones known as *vertebræ*, arranged along the back, or dorsal, surface (Fig. 333), animals possessing such a skeleton are known as *vertebrates*, or *backboned animals*. Such a skeleton is found in animals belonging to each of these five classes of vertebrates: (1) fishes; (2) amphibians (frogs and their relatives); (3) reptiles (snakes, lizards, turtles, and alligators); (4) birds; and (5) mammals.

348. Why skeletons are necessary. We have already seen that the outer coverings of animals — exoskeletons — serve as a means of protection. This is likewise true of the endoskeleton of man and of the higher animals. The brain, for example, is enclosed in the bony cranium (Fig. 346); the eyes are set in deep sockets; the delicate mechanism of the inner ear is hidden within the hardest bone of the skull (Fig. 340); and the organs of the chest cavity are protected by the ribs and breast bone. Another use of endoskeletons is that they furnish points of attachment for muscles. In these cases parts of the skeleton act as levers, which are moved by the muscles whenever the animal moves any part of its body. In a word, then, skeletons help to give animals their permanent shape; they protect delicate organs; and they provide a leverage on which muscles may act.

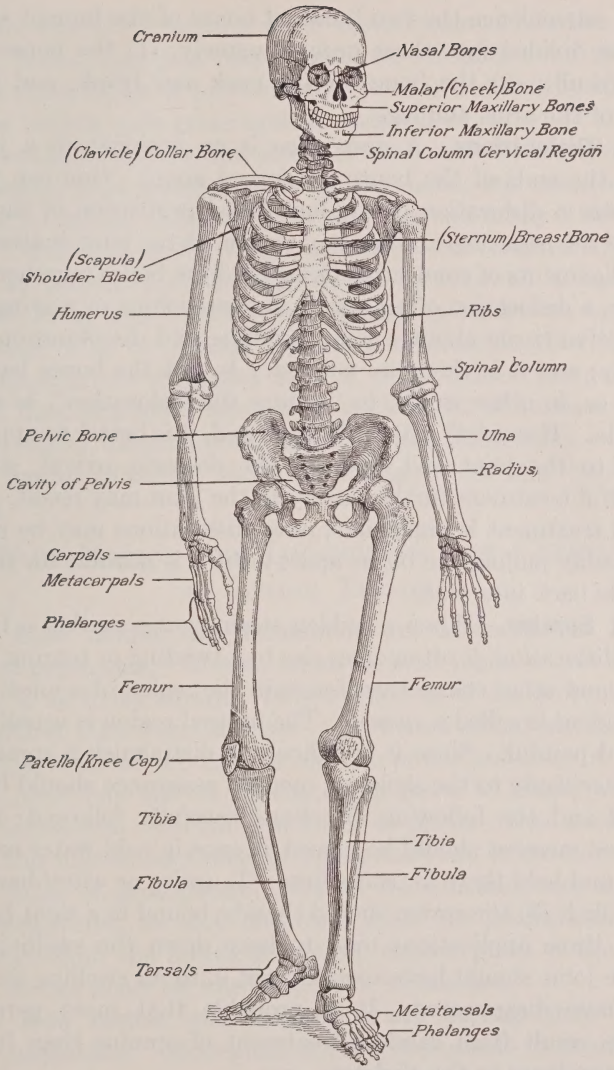


Fig. 333. — Skeleton of a man

For convenience the two hundred bones of the human skeleton may be divided into three groups; namely, (1) the bones of the head (skull), (2) the bones of the neck and trunk, and (3) the bones of the arms and legs.

349. Dislocations. A *dislocation* is an accident to a joint in which the ends of the bones are forced apart. One can usually recognize a dislocation by the unwonted protrusion of the bones and by the pain caused when any motion at the joint is attempted. Since ligaments of connective tissue bind the bones together rather closely, a dislocation often results in a wrenching or tearing of the connective tissue about a joint; swelling and discoloration follow quickly; and it is therefore necessary to put the bones back into place, or, in other words, to "reduce the dislocation" as soon as possible. If surgical aid can be procured, it is better to apply cold water to the joint and wait for the doctor's arrival, since by unskillful treatment further injury to the joint may result. When skilled treatment is impossible, most dislocations may be reduced by steadily pulling the bones apart until it is possible for the ends to glide back into place.

350. Sprains. When a sudden strain causes neither a fracture nor a dislocation, it often gives rise to a twisting or tearing of ligaments and other connective tissues in the region of a joint. Such an accident is called a *sprain*. The injured region is usually swollen and painful. Since it is difficult to distinguish a sprain from other accidents to the skeleton, medical assistance should be summoned and the following directions carefully followed: (1) the sprained member should be placed at once in cold water or in hot water and held there for some time; (2) arnica or witch-hazel may be applied; (3) the sprain should then be bound in a tight bandage (these three applications tend to keep down the swelling); and (4) the joint should have *complete rest* until all swelling and soreness have disappeared. It is probable that more permanent injuries result from careless treatment of sprains than from all other accidents to the skeleton.

351. Fractures. Any sudden strain or blow upon a bone is liable to cause a break or *fracture*, especially in later life, when the

bones are brittle. Fractures occur more commonly in the shafts of long bones, and they may usually be recognized by the fact that an extra region of movement is thus formed and by the fact that the broken ends grate against each other.

In treating a fracture, the pieces of bone must be brought back into position (this is called "setting" the bone) and must be held in place by splints until the ends have become firmly "knit" together. The setting of a bone should only be attempted by a surgeon. In general but two rules should be followed in case of a fracture: *First, send for a doctor; second, keep the broken bone perfectly quiet in as comfortable a position as possible.* Hot or cold water applications if applied at once often reduce the pain and prevent inflammation. Movement at the point of fracture almost always causes inflammation, which makes the setting difficult; and if moved suddenly, the surrounding tissues may be injured as well.

III. How Motion and Locomotion Are Carried On by Living Things

352. How motion and locomotion are accomplished by the simplest organisms. Motion seems to be a fundamental characteristic of all living things. It is a property of the protoplasm of the simplest plants and animals. In the one-celled amœba (318) the whole mass of protoplasm has the power not only of *motion* within itself but also of moving from place to place, which is called *locomotion.* Certain low forms of plants (*slime molds*) also retain this marvelous ability of self-motion and locomotion of the whole mass of protoplasm. But as we continue our study of one-celled forms, we soon find that, while the protoplasm of the cell may retain the power of motion, certain parts of the protoplasm are set apart for the purpose of locomotion.

353. How motion and locomotion are accomplished by the higher organisms. Movement of some sort seems to be universal among the higher plants. Witness the opening and closing of flowers, the turning of leaves and stems to the sun (Fig. 35), the sudden closing of the leaves of the Venus's flytrap (Fig. 75) on

being touched by an insect. These movements are brought about so differently from those of animals that it seems best not to speak of them in this connection. Locomotion, however, except in the lowest forms of plants, is limited to the animal kingdom. So generally is this true that the mere fact that an organism exhibits this power of moving from place to place at once stamps it in the minds of most people as an animal.

We have seen that even in one-celled animals like Paramecium division of labor within the animal cell is evident, since these animals have developed special parts of the protoplasm, the cilia, to carry on the process of locomotion. In higher animals this differentiation is carried still farther, and certain cells have become specially adapted to carry on all the movements essential to life. These specially endowed cells are known as *muscle cells*, and the organs of which they form the greater part are called *muscles*.

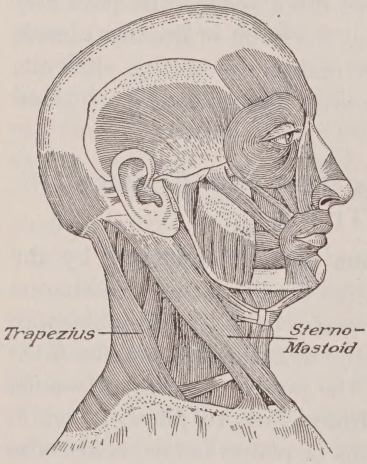


Fig. 334. — Muscles of the head and neck

Find the muscle that: closes the jaw; pulls the head forward; pulls the head backward; pouts the lips; broadens the mouth in a smile; draws down the corner of the mouth.

Muscle cells (Fig. 49) have the peculiar power of decreasing their length, that is, *contracting*, and hence increasing their breadth and thickness, and then of decreasing their breadth and thickness and thereby increasing their length (*relaxing*). When the individual cells contract, the muscle as a whole of course shortens, and if the muscle is attached to the bones of an appendage, the appendage is moved by it.

354. What the importance of muscle tissue is. Muscle tissue constitutes 41%, or almost half, of the weight of the human body. In this kind of tissue is found one fourth of all the blood. But the importance of muscle tissue is appreciated, even more fully,

when we realize that nearly every kind of movement in the body is due to the action of the muscles. They bring about not only the more obvious motions of the arms, the legs, the trunk, and the head, but also all the contractions of the heart, of the stomach, and of other internal organs. Every change in the expression of the face (Fig. 334) and every variation in the tone of the voice is likewise a result of the action of this all-important tissue. Hence we are not surprised that there are *over five hundred separate muscles,* which vary in length from the fraction of an inch (within the ear cavity) to over a foot and a half (down the front of the thigh).

355. Kinds of muscles. All these muscles are in one way or another under the control of the nervous system. Some of them are directed by the conscious portions of our brain. Thus we can close our fingers and open them as we please; we can move the eyes, the head, and the legs at will. *We call all the muscles that are controlled by our will power voluntary muscles.* Most of the muscles of the throat, those of the gullet, stomach, and intestines, on the other hand, act without any voluntary direction on our part, and they are therefore called *involuntary.*

356. The biceps muscle. When one places his left hand on the front surface of his right upper arm and then draws up his right forearm as far as possible, he feels the muscle in front of the humerus (Fig. 335) become *shorter, thicker, and harder.* If he extends the forearm again, a tough cord, or *tendon,* can be felt at the lower end of the muscle. This tendon attaches the muscle to the radius bone. The upper end of this muscle is covered by thick layers of flesh, but, if these were removed, we would find two other tendons, which connect the muscle

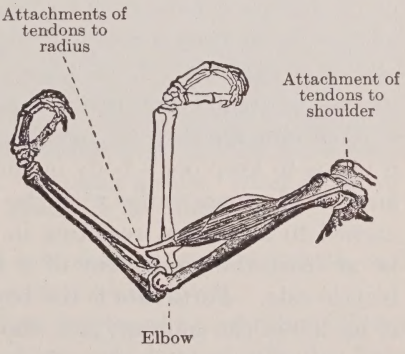


Fig. 335. — Action of the biceps

with projections on the shoulder blade (Fig. 335). The muscle we have been studying is called the *biceps*, from the fact that its upper end has two tendons. The central portion, or the part that contracts, is called the *belly* of the muscle.

357. The triceps muscle. If we straighten or extend the forearm as far as possible, the belly of a muscle behind the humerus is found to swell. This is the *triceps* muscle, so called because it has three tendons at its upper end. These tendons form the upper end of the triceps and are attached to the shoulder blade and to the humerus. The lower end of the muscle is attached to the projecting head of the ulna (Fig. 333).

358. Necessary conditions for healthy muscles. If one is to have a well-developed and healthy muscular system, four conditions must be fulfilled: *The body must be supplied with nutritious food; there must be a generous amount of fresh air; the muscles must be exercised vigorously; and this exercise must be followed by periods of rest.* We shall now consider how some of these requirements may be met.

Exercise. It seems like a contradiction to say that the only way to get more and better muscle is to destroy what we already have. Everyone knows, however, that, if the muscles of the arm or the leg are not used for a time, they become weak and flabby, and yet every time a muscle is made to contract, some of its substance is oxidized. New muscle must then be formed by the process of assimilation to take its place.

A certain amount of vigorous exercise each day is essential if one is to keep one's body in the best physical condition. This amount of course varies with the individual. It should never be carried to an excess, resulting in exhaustion, but should usually be at least the equivalent of a five-mile walk or a fifteen-mile bicycle ride. Fortunate is the boy who can spend the early years of his life in the country, and who has been taught to do a certain amount of manual work each day out of doors. Regularity in exercise is as important as regularity in eating. One can not exercise vigorously one day and expect its good effects to last for a week. We should not call upon the muscles for violent exertion

immediately after rising and before breakfast, nor should we exercise until at least half an hour after eating. The physiological reasons for these directions have been already given in our study of the circulatory system (146).

The best forms of exercise are those that call into play the greatest number of muscles. For this reason gymnasium training is better than many kinds of outdoor sports. In the gymnasium, too, special forms of exercise can be taken to develop any muscles found to be weak. On the other hand, lawn tennis, golf, rowing, and football have the additional advantage of being played in the open air, and games of this sort are usually more exhilarating than are set forms of exercise with apparatus. To secure the full effect of any kind of exercise, it should be followed by a moderately warm, then by a cold shower, or sponge bath, and by a good rubbing of the body with a coarse towel.

Fig. 336. — Standing posture. Which of the two postures is the better? Why?

Muscles are not the only tissues developed by exercise. Every muscular contraction is directed by some kind of stimulus from the nervous system. Before the muscles of the arm or leg contract, a "message" must come to them from the brain or spinal cord; hence nerve tissue is likewise developed by exercise.

Rest. If physical exertion is carried beyond a certain point, exhaustion results, and the muscles can not be made to contract until after a period of rest. Since all muscular contraction involves oxidation of tissue, periods of rest must be allowed for the muscles to get rid of their wastes and to build up new tissue in place of the old. The feeling of weariness after long-continued exercise is probably due to the presence in the body of great

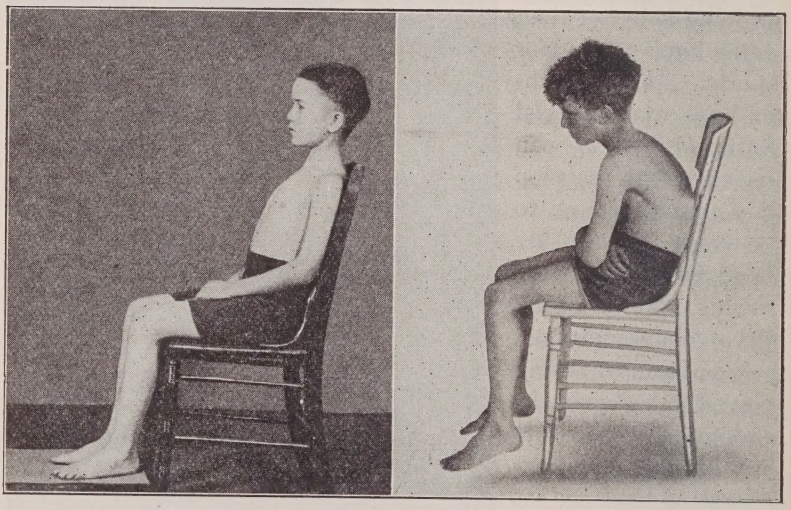


Fig. 337. — Proper and improper sitting posture
In what respects is the posture at the left better than that at the right? Compare positions of feet, back, and head.

quantities of carbon dioxid, water, and urea. One can often rest to good advantage by changing from one form of activity to another, but from eight to nine hours of sound sleep each night are indispensable for the health of a growing youth.

359. Relation of muscles to proper posture. An erect posture and graceful carriage not only add to pleasing appearance but are important in maintaining the health. Round shoulders and stooping position decrease the capacity of the chest and interfere

seriously with the action of its organs. It is important that boys and girls acquire a good posture early in life and that they realize that *this is largely a matter of muscular training.* In standing (Fig. 336), the head and body should be erect, the heels brought close together, and the shoulders brought into such a position that the back is approximately flat. In sitting (Fig. 337), care should be taken not to bend the body over the desk, and a proper relation between the height of the chair and that of the desk should be secured.

Permanent curvature of the spine frequently results from carrying loads of books or other heavy objects on one side of the body only; pupils should therefore train themselves to use the arms alternately for this purpose.

IV. How the Eyes and Ears Should Be Cared For

360. In what ways eyes are defective. A normal, healthy eye has the power of adjusting itself so that objects become visible which are within five to ten inches or as far away as a distant horizon (Fig. 338). Many people, however, find that they can see objects near at hand much more clearly than those at a distance; in other words, these people are *nearsighted;* others, on the other hand, are *farsighted.* These defects in vision are due to imperfect formation of the eye and can be corrected only by the use of proper *eyeglasses or spectacles. Glasses should be purchased only on the recommendation of a competent eye specialist.*

Another very common defect of the eye is known as *astigmatism.* Many people, on looking with each eye separately at Fig. 339, find that some of the radiating lines stand out sharply defined, while others are indistinct or blurred. In reality, all the lines are equally distant from each other, and the indistinctness referred to above is due to the fact that some of the rays of light are not brought to a focus. Astigmatism, like nearsightedness and farsightedness, should be corrected by the use of proper glasses; otherwise constant eyestrain is likely to cause headaches and other disorders of the body.

Some people, too, are unable to distinguish clearly various colors; thus red and green may appear the same to them. In other words, such people are *color blind*. Color blindness can not be corrected by glasses but may be to some extent by training.

361. How the eyes should be cared for. The eyes have, as we know, wonderful powers of adapting themselves to varying conditions. This adaptability often leads us to abuse them.

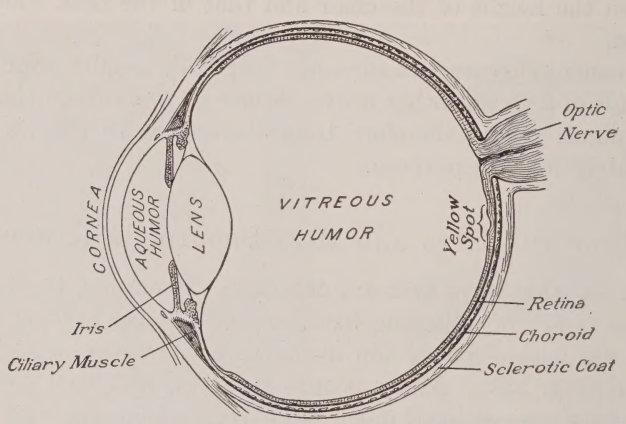


Fig. 338. — Structure of the eye

In the eye we have an arrangement similar to that of a camera, since the convex surfaces of the cornea and crystalline lens focus the rays of light so that an image is formed on the sensitive retina at the back of the eye. Since, however, the lenses within the eye can not be moved backwards and forwards, as in a camera, focusing or *accommodation* of the eye must be accomplished in a different way; namely, by making the elastic lens more or less convex.

Thus we frequently read when the light is insufficient, we look steadily at objects until we suddenly find that we can not see clearly, and we read or study while riding in swiftly moving trains. In these and other ways we compel our eyes to make adjustments under trying conditions, and more or less severe eyestrain is sure to follow.

When we read, we should make sure that the light is sufficient, that it is steady, and that it comes over the left shoulder. The type on the printed page should be little, if any, smaller than that

in which these words are printed, the lines should not be close together, and the paper should not have a glossy surface to reflect the light into the eyes. One should remember too that the eyes, like other organs of the body, need frequent periods of rest. Hence study hours should be followed by periods in which the eyes are allowed to relax. Pupils who have defective eyesight should at once secure proper glasses.

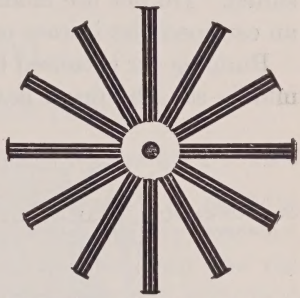


Fig. 339. — Test for astigmatism

Do all of these lines look equally clear to you?

362. How the ears should be cared for. In case the outer ear is frozen, it should be thawed out slowly by the application of snow or ice. The external ear and the auditory canal (Fig. 340) should be kept clean and should be thoroughly dried, especially after bathing. If ear wax accumulates, it should be removed by a doctor; do not try to do it yourself. In case a foreign body gets into the ear canal, do not get excited or try to remove it without help from a doctor; more harm often results from the effort to remove the obstruction than from the object itself. If an insect crawls in, a little warm water or sweet oil gently dropped in will usually remove it, or a light held near the ear will attract it and cause it to crawl out. The advice given by an old doctor is wise advice: "Never poke anything into your ear or scratch it with anything but your elbow!"

In blowing the nose only one nostril should be closed at a time, and care should be taken not to blow too violently, since germs and mucus may be forced from the throat cavity up the Eustachian tube into the middle ear, thus causing infection of the middle ear. For a similar reason, after spraying the nose, liquid should not be snuffed up too violently; it should be allowed to run out, and five minutes should elapse before blowing the nose.

Earache may be caused by a cold or by the closing of the Eustachian tube (Fig. 340). A hot water bottle or a hot flatiron wrapped in flannel or a bag of hot salt should be held over the

outer opening of the ear. Soft food should be eaten, and a rest should be taken. If pain continues, a physician should be consulted. Do not use laudanum or any patent medicine. Consult an ear specialist in case of any ear trouble.

Running ear is caused by the discharge of pus from an inflamed middle ear, the drum having been perforated by the pressure of

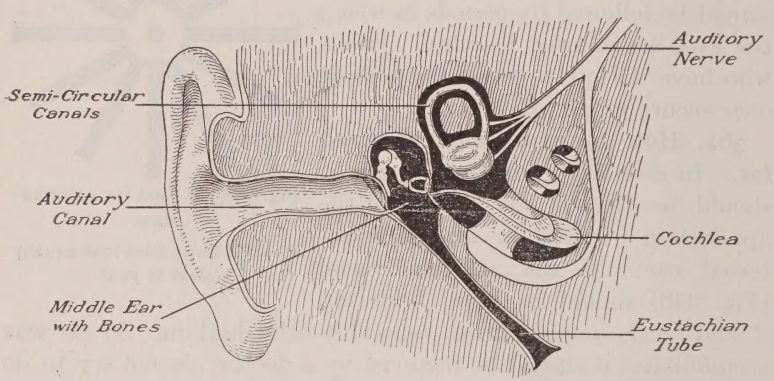


Fig. 340. — Diagram of the principal parts of the ear

Note the eardrum at the inner end of the auditory canal, the three tiny bones of the middle ear, and the spiral cochlea and the canals of the inner ear. When sound waves enter the tube of the external ear, they cause the eardrum to vibrate, and this vibration is transmitted across the middle ear by the chain of tiny bones, and so reaches the complicated inner ear, which is a series of canals imbedded in solid bone. The inner ear contains a large number of sensitive cells which transfer the vibrations to nerves communicating with the brain. When the brain cells receive and interpret these impulses, we get sensations of sound.

the liquid trying to force its way out. This often is a result of colds or of adenoids. A gathering in the ear is an accumulation of pus that can not escape by way of the Eustachian tube because it has become clogged up. If a gathering in the ear or a running ear is neglected, the poisonous material may work its way inward and cause *mastoiditis*, which is an infection of the mastoid cells in the bony projection that is felt on the skull back of the outer ear. Repeated perforations of the drum head may result in deafness. Temporary deafness may also be due to a closing of the Eustachian tubes.

CHAPTER XXVI

HOW OUR BODIES ARE CONTROLLED

I. Some General Functions of the Nervous System

363. The human body as a collection of organs. In previous chapters we have considered the digestive, respiratory, and circulatory systems of the human body, and we have seen how the organs of these systems furnish all parts of the body with food and oxygen and take away the wastes. We have studied the process of oxidation whereby we keep warm and gain the power to do work. And, finally, we are familiar with the fact that the bones and muscles are the organs that give support to the body and provide the machinery for all our motions. Thus we have learned that the body is composed of many organs, each with its special function or functions.

364. What is meant by coöperation of the organs. A human being is more than a mere collection of working organs, for *all the organs work together for the common good.* This is what we mean by *coöperation.* Suppose we take a few instances from everyday experience to illustrate this coöperation.

When food is taken into the mouth, the salivary glands pour out upon it an abundant supply of saliva. Now the food never comes in contact with the glands. How is it, then, that they send out their secretion at just the right time and in the proper amount?

If a blow is aimed at the face, our hands immediately fly up to ward off the threatened injury. If the attack were pressed and we were compelled to defend ourselves, our hearts would beat much more rapidly, we would breathe faster, and a flow of perspiration would become evident. During the contest certain feelings, like those of fear or anger, also would doubtless be aroused. What is the explanation of this coöperation among our organs?

365. Into what three classes the activities of our bodies may be divided. The functions carried on by the body are for the most part directly or indirectly *under the control of the nervous system.*[1] For practical purposes these various activities fall into three groups, according to the amount of conscious attention required to perform them.

Group I includes *our conscious, or voluntary, activities* — those that require attention to perform them. As examples of these conscious activities we may mention the selection of the books needed for study, the sustained attention we must give in order to learn the lessons that have been assigned, and the choice of foods that we make at lunch time.

Group II comprises the *acquired, or habitual, activities* — those that required attention at first but not at the present time. These activities are acquired by repeated performance; we call them our *habits.* For example, a student comes to the classroom; and as he hears the gong strike, he takes his seat and is at once ready for the work of the recitation period. Ordinarily he does not need to take any thought in regard to this matter, that is, if he has coöperated for a number of years with good school discipline, for he has done these acts so often that they have become "second nature."

A moment's thought, however, will convince us that the actions which we have been describing were once wholly conscious acts. When you first went to school, you had to learn that the sound of a given bell meant silence. If you wish to do so, even now in the high school period, you might direct your muscles in such a way that you would remain standing and continue to talk even after the signal for silence has been heard. In a similar way we could easily show that a very large part of the doings of each day (*e.g.* dressing, walking, talking, eating) was once wholly under conscious direction.

[1] Each student might be asked to make as complete a list as possible of the activities he has carried on through the help of the muscles, glands, sense organs, or brain during a period of twenty-four hours, both while awake and asleep. It will be well from these lists to develop on the blackboard a daily routine for a high school student, attention being called to the hygienic significance of each act. Two or three recitation periods might be devoted profitably to this study.

Group III includes those *native, or involuntary, activities,* like breathing, beating of the heart, secretion of glands, which never have required any conscious attention for their performance. Since all these functions were performed from birth practically as well as at the present time, we call them also *inborn,* or native, activities.

Each of these classes of activities will be discussed more or less in detail later; but before we can proceed further with our studies of nerve functions, we must get some idea of the structure of our nervous system.

II. How Our Nervous System Is Constructed and How It Works

366. What we know of the general structure and action of the nervous system. The human nervous system is shown in outline in Fig. 341, as it would appear if viewed from the back. We see that the larger portion of the upper part of the head (*cranium*) is filled with the *brain* and that from the brain the *spinal cord* extends downward through a canal in the spinal column of the neck and trunk regions. Forty-three pairs of *nerves* are connected with the two *nerve centers* (brain and spinal cord) that we have just named. These nerves branch out to all parts of the body.

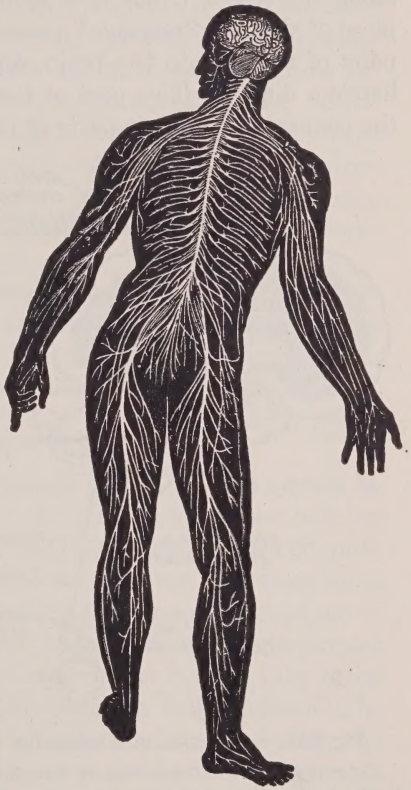


Fig. 341. — General structure of the nervous system

Note the brain, spinal cord, and the nerves that connect with all parts of the body.

In many ways our nervous system resembles a telephone system, the nerves corresponding in function to the wires, and the brain and spinal cord to "central." For example, while walking along the street, if our eyes light upon a shining white circular piece of silver, a "message" passes from the eyes along one of the pairs of nerves into the brain, and we say to ourselves, "Hello! here's a dime!" This part of the brain "central" switches over the connection to other parts of the brain. "Messages," or *stimuli*, are sent down the spinal cord and out along the various nerves that connect with the muscles of the arms and the legs. We stoop over, grasp the coin, and meanwhile experience a feeling of satisfaction at this piece of good luck.

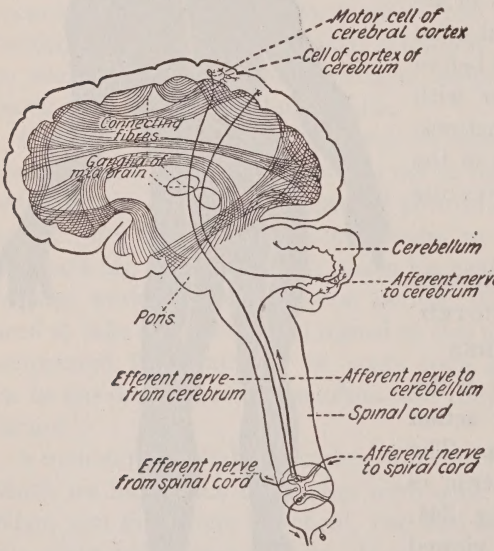


Fig. 342. — Diagram of a section of the brain

Trace the course of the nerves up from the spinal cord to the brain; down from the brain through the spinal cord.

367. How activities are brought about by the nervous system. A hundred experiences of our daily life much like this might be described. Each one of them, on careful analysis, is found to consist of five more or less distinct parts, as follows: (1) some kind of *stimulus must be received* from the exterior of the body; (2) an *impulse must be carried in* to nerve centers along certain nerves; (3) the *nerve centers must make more or less complicated connections;* (4) some kind of *stimulus must be sent out* from the nerve centers along other nerves; and (5) this *impulse must act* upon muscles,

glands, or some other kind of organ of the body in such a way as to control the work of the given organ.

Biologists have proved that the nerve threads, or *nerve fibers*, for incoming messages are entirely distinct from those that carry outgoing messages. To the nerves that carry incoming messages is given the name *afferent* (from the Latin, meaning *to carry to*), since they always carry stimuli *to* nerve centers (Fig. 342). *Efferent* nerves (from the Latin, meaning *to carry from*), on the other hand, are nerves that convey stimuli *out from* the nerve centers. To the parts of the nervous system concerned in making connections between afferent and efferent nerves is given the name *adjustors*.[1]

Hence, in order to carry on each of our functions, receptors must transmit their impulses to afferent nerves, which bring the messages to the nerve centers. Here the adjustors switch over the message to the efferent nerves, which convey the stimuli to the effectors. These, in turn, bring about the countless activities of heart, stomach, hands, and feet.

368. What the microscopic structure of the nervous system is. We come now to a description of the cells of which the nervous system is composed. To Golgi, an Italian biologist, who published an important paper in 1873, we owe our first clear ideas of the real cellular structure of the nervous system. By the use of special staining fluids, he found out that most nerve cells are far more complicated than any other cells of the body. Like other cells each nerve cell has near the center a cell nucleus. The cell body, however, is extremely irregular in form, and since the branching processes from the cell body resemble to a considerable extent the trunk and branches of a tree, these processes are known as *dendrites* (from the Greek, meaning *tree*).

In Fig. 343 we see one of these nerve cells with its dendrites and an additional process which does not branch so extensively, but which may extend for a considerable distance from the cell

[1] The cells on or near the exterior of the body which receive messages of temperature, pressure, light, and sound vibrations and transmit these messages to the afferent nerves are known as *receptors*. On the other hand, the nerve endings in muscles or glands are known as *effectors*, because of the effect that results from a nerve stimulus.

body. This is known as the *axon*, or axis-cylinder, process. At a short distance from the cell body this process becomes inclosed within two layers of material, which probably act more or less like the insulations or coverings that inclose telephone wires, to prevent the nerve stimulus from crossing over to another axon. The axon, after a longer or shorter course, finally ends in a muscle, gland, or other organ in several *terminal branches*.

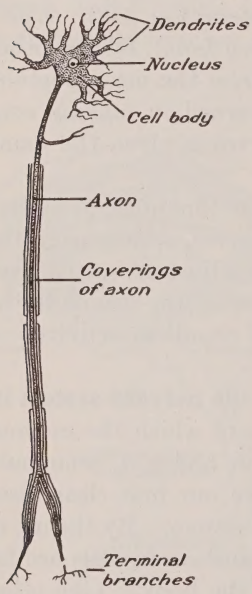


Fig. 343. — A neuron

So we see that nerve cells are extremely irregular in shape, due to the fact that the cell body extends outward in the form of branching dendrites, and also in the form of an axon. All these extensions of the cell body bring a nerve cell into relations with other nerve cells or with other parts of the body. To the whole nerve cell with all of its processes, including the axon, is now given the name *neuron*.

369. What the nature of nerve stimuli, or impulses, is. We have likened nerve fibers to telephone wires, and nerve stimuli, or impulses, have been described as "messages" that pass along the axones. But in making these comparisons we must remember that telephony has, in all probability, little real resemblance to the action of the nervous system. In the first place, we know that the nerves of a frog transmit impulses at the rate of about 100 feet per second, which is about as fast as an express train travels when it is going 70 miles an hour. In man the nerve impulses travel about 270 miles an hour. An electric current, on the other hand, is transmitted thousands of miles per second; hence, a nerve impulse can not very closely resemble a telephone "message" at least in speed. We must admit our ignorance as to the real nature of nerve stimuli; and we are still more in the dark as to what takes place in nerve cells after "messages" are

received. No scientist has any idea as to how consciousness, feelings, and volition, or "will power," can arise as a result of nervous activity.

370. How the native, or involuntary, activities of our bodies are controlled. In Fig. 344 we see represented a lengthwise section

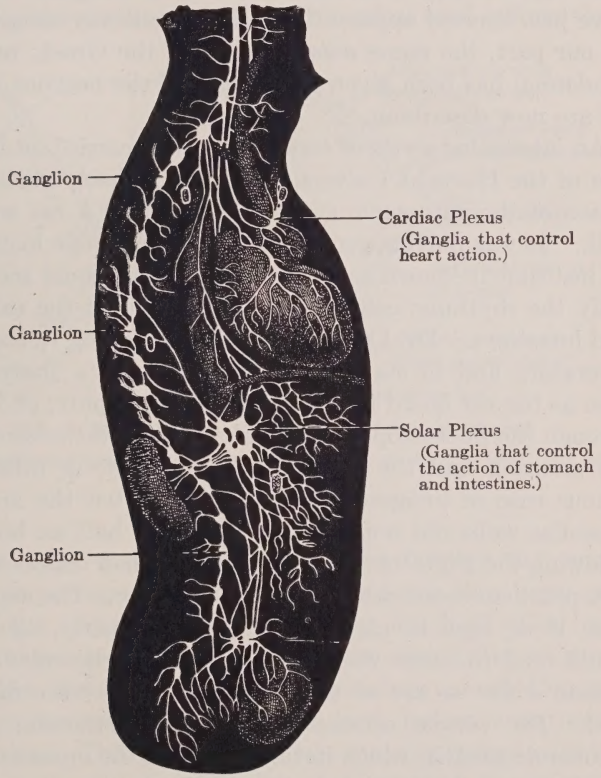


Fig. 344. — Autonomic nervous system

of the human body with the heart, the diaphgram, and one kidney faintly outlined. Along the side of the spinal column, we observe a series of little enlargements connected with each other by nerve fibers. These are also connected with the nerves that run off from the

spinal cord. Each of these little enlargements is known as a *ganglion* (plural, *ganglia*). A similar string of ganglia is also found on the other side of the spinal cord, although not shown in the picture. It is these ganglia, or tiny nerve centers (substations), that control the organs of circulation, digestion, excretion, and other involuntary activities. Since these organs to which we have just referred apparently work without any conscious control on our part, the name *autonomic* (from the Greek, meaning *self-regulating*) has been given to the part of the nervous system that we are now describing.

An interesting series of experiments was carried on by Dr. Cannon of the Harvard University Medical School, which shows the action of the autonomic system of ganglia. A cat was fed with milk. It was purring contentedly; and when one looked through an instrument known as the *fluoroscope*, one could see within the body the rhythmic contraction of the walls of the cat's stomach and intestines. Dr. Cannon then allowed a dog to come into the laboratory and to stay long enough to give a sharp bark. As soon as the cat heard this noise, it ceased to purr; and on looking through the fluoroscope, one could see that all the contractions of the stomach and the intestines had ceased; in other words, a serious case of indigestion had set in. Often the action of the muscular walls did not start up again for half an hour or more following the fright or anger that the cat had experienced.

A practical lesson which one can learn from the experiments is that, if we wish to carry on digestion properly, all topics that would tend to cause worry or anger should be ruled out of discussion while we are at the table or while we are digesting our food. The various *emotions* that we have, therefore, affect the autonomic ganglia, which in turn act upon the organs of digestion, circulation, and other involuntary activities.

371. What the structure of the spinal cord is. The spinal cord extends from the base of the brain downward inside the spinal column. It gradually tapers off to a point in the region of the middle of the back. When we look at a cross section of the spinal cord (Fig. 345), we find that it is nearly divided in half.

In the interior of the cord is a region shaped more or less like a capital letter H. This consists of *gray matter*, and inclosing the gray matter is the *white matter*. Connected with the gray matter on either side are the nerve fibers that form the various spinal nerves. It has been stated that these nerve fibers are of two kinds: those which carry messages into the spinal cord (afferent) and those carrying the messages out from the spinal cord (efferent).

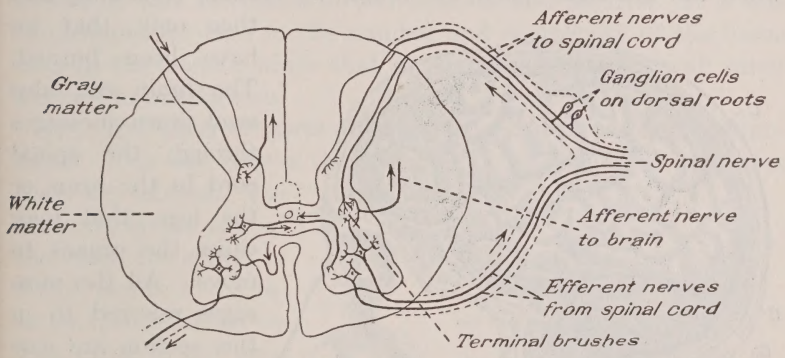


Fig. 345. — Diagram of a cross section of the spinal cord

Find neurons that bring messages: to the spinal cord; across the cord; out from cord; up to the brain.

372. How reflex action is brought about through the spinal cord. We can perhaps make clear how this nerve machinery acts by considering a simple experience like that which all of us have had when unexpectedly we touched a hot object like a stove. We know that the hand is instantly withdrawn, and that too without any conscious thought on our part, indeed even before we feel the burn. This is due to the fact that the receptors in the skin, having been stimulated by the heat, transmit the stimulus through the afferent nerves to the gray matter of the spinal cord, where the nerve cell bodies are located. Here a connection is made with the efferent nerves, and the stimulus is immediately transmitted by these nerves to the effectors in the muscles. The muscles contract, and the hand is removed from danger. This

kind of action is known as a *reflex action.* It consists of an incoming stimulus, a connection made in the spinal cord, or "central," and an outgoing message to the contracting muscle.

373. How messages reach the brain through the spinal cord. In addition to its function in connection with reflex action, the spinal cord sends messages up to the brain (Fig. 343). In the experience of touching the hot stove to which we have just referred, when the messages reach the brain, we become conscious, and then only, that we have been burned. The brain can also send down messages through the spinal cord to the arms or the legs, that may cause the organs to move. All the messages referred to in this section are carried through the white matter of the spinal cord.

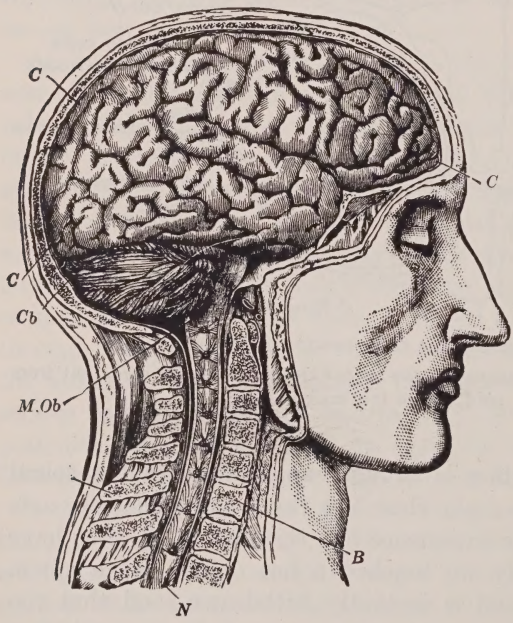


Fig. 346. — Section of head to show brain
C, cerebral hemisphere; Cb, cerebellum; N, spinal nerve; M.Ob., medulla oblongata.

374. How a side view of the human brain appears. Let us now study a side view of the brain as it appears when the skull has been removed (Fig. 346). The largest portion of the brain consists of the two *cerebral hemispheres* (the right one is shown in the figure). Below the cerebral hemispheres is the *cerebellum.* We notice that the outer surface of the brain consists of a number of elevations, or *convolutions,* which look more or less like a succes-

sion of irregular mountain ranges. Between these convolutions there are depressions, or valleys, some of which are known as *fissures.*

In the brain the *gray matter is on the outside,* and not towards the center as was the case in the spinal cord. Since gray matter, wherever found, is always composed of the bodies of the nerve cells, it is evident that the outer surface of the brain and consequently the number of nerve cells is considerably increased in extent by this succession of convolutions and fissures. It is this tremendous increase in the number and complexity of the nerve cells in the human brain that places man high above all other animals in intelligence.

375. Are different parts of the brain set apart for special functions? The side view of the brain in Fig. 347 shows certain areas that are labeled. For instance, in the rear of the brain the center of *vision* seems to be located. Hence the nerves that bring in the messages from the eyes must finally bring their messages to this region of vision in the cerebral hemispheres. In a similar way the nerves from the ears carry their stimuli to the side region of the brain marked *hearing.* Along the side of the brain, too, are the regions of the cerebral hemispheres that control the muscles of the *leg, arm, face, lips, tongue, and organs of speech.* These facts we have just stated have been proved by long series of experiments upon animals and by observations of diseased conditions of the brain among human beings.

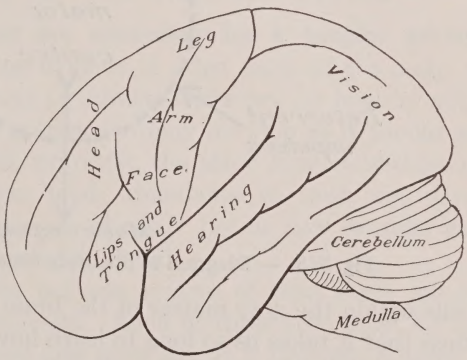


Fig. 347. — Side view of the brain
Note the locations of functions.

376. How connections are made from one part of the brain to another. In Fig. 342 we have represented a very few of the

possible lines of connection from one part of the brain to another. These connections are brought about by nerve fibers that run from one convolution to another (Fig. 342) or from the convolutions of one cerebral hemisphere of the brain to those in the other hemisphere. No telephone system in all the world is anything like so complex in its connections as are the possible connections between the various cells of our nervous system. By means of these connecting fibers we are enabled to do the complicated acts which it is possible for an intelligent human being to accomplish. It is estimated that there are ten billions (10,000,000,000) of nerve

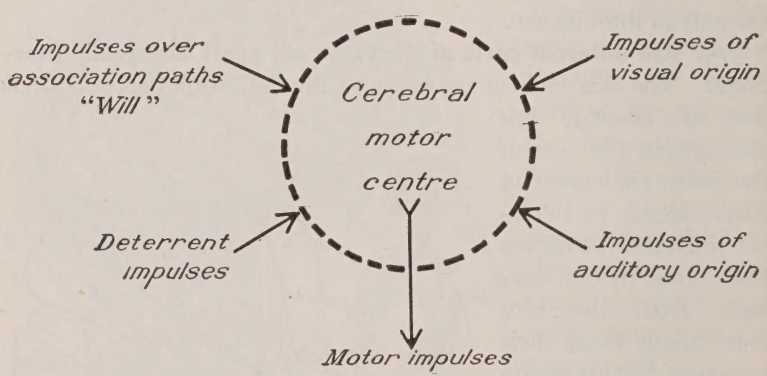


Fig. 348. — Diagram to illustrate conduct. (After Stiles.)

cells within the gray matter of the brain alone. Is it any wonder then that it takes us so long to learn how to do the various things which we finally learn to do? How fortunate too that, when once we have trained ourselves to walk, to write, to play the piano, we then can leave these *habitual activities* to themselves and give our attention to other things. (For further discussion of habits see the next chapter.)

377. Upon what our conduct depends. If we study carefully Fig. 348, it ought to teach us a great many valuable lessons. Let us suppose that a boy is near a fruit stand. "Impulses of visual origin" come into his brain, as he sees an orange he would like to eat. The temptation is increased by "impulses of auditory origin," when he hears another boy whisper to him to grab the

orange. Were this all of his experience, his "cerebral motor center" (*i.e.* his brain) thus appealed to would doubtless send out "motor impulses", and the youth would seize the orange.

Fortunately, however, "deterrent impulses," which would tend to hold the boy back, are quite likely to act upon him. For example, he is quite likely to remember that the orange does not belong to him. He may think of the shame that would come to himself and to his family if he is caught stealing. And so, let us hope, these deterrent impulses together with "impulses over association paths" (namely, "will power") will cause his cerebral motor centers to send out motor impulses that will take him out of the reach of temptation.[1]

III. Hygiene of the Nervous System

378. What conditions are necessary for a healthy nervous system. In studying the hygiene of other parts of the body, we found that four conditions are always necessary for healthy activity. That the nervous system too may develop as it should and that it may do its work properly, the same four conditions are essential; namely, proper food, abundance of fresh air, varied forms of activity, and periods of rest. Let us now consider each of these conditions somewhat in detail.

Food and air. In the nervous system of man there are uncounted billions of nerve cells. Each of these cells must be supplied with nutritious food and pure air, or it becomes stunted in its growth and unable to do its proper work. Each of these busy cells is constantly giving off carbon dioxid, water, and other wastes; and if these are not removed from the body and fresh oxygen supplied, one feels a drowsiness and headache and is unable to think clearly. Well-ventilated rooms, both by day and by night, are of prime importance in the hygiene of the nervous system.

[1] As a result of general discussion of this diagram, the class can doubtless make other practical applications of the principles that determine right and wrong conduct. For instance what determines whether a given boy will or will not cheat in examinations? Whether a soldier will be a coward or a hero in time of battle?

Varied activity and rest. To develop a well-balanced brain one must be active along many lines. Experience tells us that we can not work successfully at the same task hour after hour without some change. Hence, varied activity is an important principle in sound education. The young child must, of necessity, turn, after a short time, from one lesson to another, and all lessons must finally give way to the relaxation of play. Unfortunate is the boy who fails to find exhilaration in baseball, bicycle riding, or general athletics, for these sports, when properly regulated, besides developing strong lungs and vigorous muscles, are important means of educating the nerve cells and fibers.

Not only in youth, but throughout life, must the student, the business man, or the laborer, at the end of a day's employment, find relaxation in other forms of activity. If he fails to do this, not only will he become weary of his work, but he will also finally come to lose the power of enjoying the pleasures he has been neglecting. In the later years of his life, the great naturalist Charles Darwin wrote as follows: "My mind seems to have become a kind of machine for grinding general laws out of large collections of facts. . . . If I were to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for perhaps the parts of my brain now atrophied would thus have been kept alive through use. The loss of these tastes is a loss of happiness and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature."

Tired nerve cells can be restored by rest alone. In childhood and youth an abundance of sleep is absolutely essential for healthy development. Late hours of evening entertainment or of study should never be allowed to keep growing boys or girls from having at least nine hours of sleep.

379. Effect of alcohol on the nervous system. "The effect of alcohol appears to be, as it were, to shave off the nervous system, layer by layer, attacking first the highest developed faculties and leaving the lowest to the last, so that we find that a man's judgment may be lessened, though at the same time some lower facul-

ties, such as the imagination and emotions, may appear to be more active than before. . . . Thus you find that after a man has taken alcohol his judgment may be diminished, but he may become more loquacious and more jolly than before. Then after a while his faculties become dull; he gets stupid and drowsy. . . . Later on it affects the motor centers, probably the cerebellum, so that the man is no longer able to walk and reels whenever he makes the attempt. At this time, however, he may still be able to ride (on horseback), and a man who is so drunk that he cannot walk and cannot speak may ride perfectly well. . . . Later on the further anæsthetic action of the alcohol abolishes sensation, and its paralyzing action destroys the power of the spinal cord, so that the man is no longer able even to ride; but still the respiratory center in the medulla will go on acting, and it is not until enormous doses of alcohol have been given that respiration becomes paralyzed.

"Alcohol . . . makes all the nervous processes slower, but at the same time it has the curious effect of producing a kind of mental anæsthesia, . . . so that these processes seem to the person himself to be all quicker than usual, instead of being, as they really are, much slower. Thus a man, while doing things much more slowly than before, is under the impression that he is doing things very much more quickly. What applies to these very simple processes applies also to the higher processes of the mind; and a celebrated author once told me that if he wrote under the influence of a small quantity of alcohol, he seemed to himself to write very fluently and to write very well, but when he came to examine what he had written next day, after the effect of the alcohol had passed off, he found that it would not stand criticism." [1]

IV. The Chemical Controls of the Body

380. How the chemical control of the body was discovered. Not so many years ago, an account of the controlling agencies of the body would have begun and ended with a study of the

[1] T. Lauder Brunton in *Lectures on the Action of Medicine*, pp. 190, 191, 194.

nervous system and its functions. Such an account would now be considered incomplete even in an elementary textbook. In the case of the nervous system, as we have seen, control is exercised by means of impulses, or "messages", that are sent out from the nerve centers through various nerve fibers to various organs of the body. These nerve centers may be caused to act by other messages that come in from the outside of the body through other sets of fibers. While the nature of these impulses is not as yet understood, their effects are well known.

For over a hundred years it has been known that the nervous system is not the only means by which the varied activities of the organs of the body are stimulated and controlled. As a result of the careful investigations of many scientific investigators there has gradually been accumulated a great store of knowledge concerning a very different agency of control which is called the *chemical control.*

381. How chemical control is evident in the action of the pancreas. You have learned that when the food from the stomach enters the small intestine, the pancreatic juice is poured out over it. This action was formerly supposed to be caused by messages through the nervous system sent to the pancreas. It is now known that this action on the part of the pancreas is due to a *chemical messenger* formed in tiny gland cells of the mucous membrane of the small intestine. When some of the food from the stomach is forced into the small intestine, it stimulates the formation of a chemical substance (*secretin*) which is absorbed by the blood and carried through the body till it reaches the cells of the pancreas. The pancreas, then, is caused to act by the chemical substance carried to it by the blood from glands in another part of the body.

382. How insulin is related to diabetes. You have doubtless heard of the disease *diabetes.* One who has this disease can not store or oxidize sugar. Consequently sugar accumulates in the blood to such an extent that it acts as a poison. Much of the sugar is excreted by the kidneys. It has been proved, however, that this disease is caused by the failure of the pancreas (Fig. 97)

to produce a chemical substance, which, when absorbed by the blood and carried to the liver cells, enables them to store up sugar. When this substance is absorbed by other cells like those of muscle, these cells are enabled thereby to oxidize the sugar. This chemical substance has been called *insulin*.

During the year 1923, Dr. F. G. Banting of the University of Toronto devised a method of preparing insulin from the pancreas of the sheep. When insulin is injected into the blood of a diabetic patient by experts in this method of treatment, the patient is able to store and oxidize the sugar. The use of insulin must, however, be continued; it is not a cure of the disease.

383. What the internal secretions are. The *secretin* of the glands of the small intestine and the *insulin* of certain gland cells in the pancreas are examples of chemical substances that either alone or with the aid of the nervous system control and regulate vital activities of the body. Since these secretions are absorbed by the blood and are not poured out through ducts upon some free surface, as are saliva and gastric juice, they are known as *internal secretions*, and the glands that form these chemical substances are known as *glands of internal secretion*. The substances that these glands secrete are also called *hormones* [1] (from the Greek, meaning *exciting*).

But glands of internal secretion are not limited to those mentioned above. There are at least seven other glands which secrete one or more hormones; each one has one or more functions. The following is a very brief account of three of these vital, wonder-working glands.

384. Adrenal glands and adrenalin. The adrenals are small glands located near the kidneys (Fig. 349), as the name "adrenal" indicates. It is said that for hundreds of years these glands were neglected, since they were thought to be a part of the fat that was found on the kidneys. A hormone, *adrenalin*, has been obtained from the outer part of these glands. One of the functions of adrenalin seems to be just the opposite of the function of

[1] Hormones are also called *endocrines*, and the glands that secrete them are known as *endocrine glands*.

the insulin of the pancreas. It was stated, you will recall, that insulin makes it possible for the liver to store sugar. Now adrenalin, when it reaches the liver, causes sugar to be given into the blood stream, and, when the sugar reaches the muscles, it affords a fuel from which energy may be readily released. Since the adrenals are especially active in secreting adrenalin, in case of emergency they are very essential to enable one to defend himself or to escape in case of danger. It is the extra secretion of adrenalin that enables a person to perform seemingly superhuman acts. The adrenals are sometimes called the *glands of combat*, because they prepare one for a physical struggle. Animals that are the most pugnacious have in proportion to the size of their bodies the largest adrenals. It is said that man has larger adrenals than any other animal. No one can long survive the removal of the adrenals.

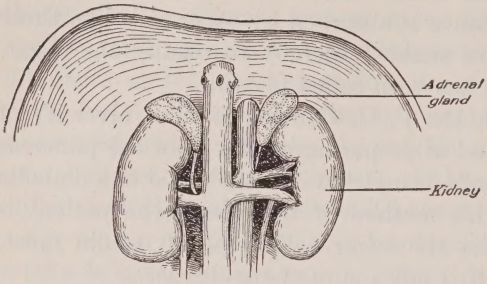


Fig. 349. — **Adrenal gland** (After Stiles).

385. The thyroid gland. This consists of two maroon-colored masses on either side of the neck above the windpipe and close to the larynx (Fig. 350). The secretion of the gland is known as *thyroxin*. It is thyroxin that regulates the rate at which energy is released. It is therefore said to regulate the speed of living. That is, the more thyroxin one has, the more rapidly food materials are oxidized, and therefore the individual feels, thinks, and acts more quickly. An excessive development of the thyroid

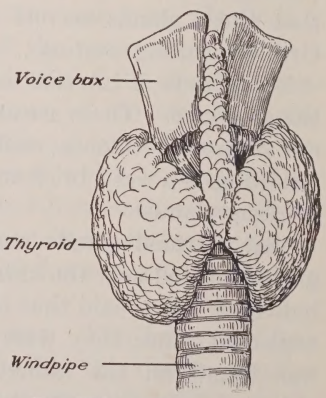


Fig. 350. — **Thyroid gland** (After Stiles).

gland, however, may lead to very serious results, and thyroid deficiency may give rise to even more serious consequences.

In extreme cases the child that is deficient in thyroid secretion will never develop either physically or mentally and will be unable to recognize father or mother or show any interest in toys or any other objects. Experiments have been tried in feeding such children with thyroid extract. The results in some cases are said to be nothing short of marvelous. A child that was an idiot gradually became an apparently normal child. The only drawback is that the feeding of thyroid must always continue, or the child will revert to the idiotic state.

People suffering from the special type of idiocy which is due to thyroid deficiency are known as *cretins*. The word cretin means simple-minded. At the time the name "cretin" was first given, it was not known what was the cause of this type of feeble-mindedness. One of the serious results of an overdeveloped thyroid gland is known as *goiter*. You may have seen persons having the front of the neck very much enlarged. This is due to an abnormal growth in an enlarged thyroid gland. If the goiter is not checked by skillful treatment, it is very likely to cause death.

386. The pituitary gland. This is a tiny gland, no bigger than a pea, located in the human skull at the base of the brain. An account of the effects of one of the hormones from this small gland reads like some of the fairy stories with their tales of giants and pygmies.

Have you ever seen the giants and dwarfs at a circus? If you have, didn't you wonder what had caused them to differ so in size from yourself? Would you suppose, however, that such a little body as the pituitary gland might be responsible for a baby's remaining a child in size or developing the huge body of a giant? Yet this is just what seems to be true, for a certain part of the pituitary gland secretes a hormone known as *tethelin* that promotes the growth of the skeleton. Therefore if a baby is born with an abnormally large pituitary gland, there will probably be an unusual amount of tethelin secreted, and as a result the child becomes a giant. If, on the other hand, this gland is deficient in size or in

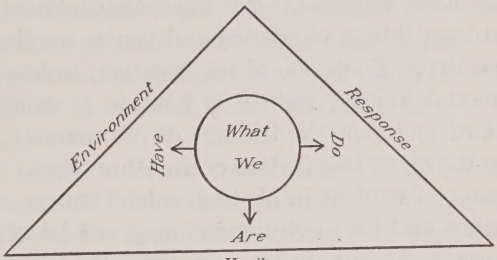
the amount of tethelin produced, the body fails to grow to anything like normal size and may remain very small indeed.

Experiments have been tried on young animals to show the effect of tethelin. The animals that were fed tethelin grew faster than those that were not fed this hormone. The experiments afford the hope that in the near future tethelin from animals may be used to promote the growth of babies that would otherwise become dwarfs.

CHAPTER XXVII

HOW SUCCESS IN LIFE IS WON

387. Upon what three factors success in life depends. Dr. Walter in his book, *Genetics*, introduces a diagram (Fig. 351) that will well repay our study. Here we have each human life represented as a three-sided affair, which Dr. Walter refers to as "the triangle of life." Since what we really *are* depends to so large an extent on our *heritage*, this factor is represented as the base of the triangle; and this, as we notice, extends to a greater distance than does either of the other two sides. Our heritage of course can never be changed, since we can not determine what we receive from our parents, grandparents, and other more distant ancestors, who are countless in number. We should remember too that this factor of our being includes not only physical characteristics, such as color of hair or of eyes, complexion, relative tallness or shortness, but also mental capacity, and quite possibly moral tendencies.



From Walters' Genetics

Fig. 351. — The triangle of life

In the second place, each one of us is surrounded by an *environment*, which, as the diagram shows, includes what *we have*, or possess. The environment of a given person may be good, fair, or poor and so may be favorable to success or unfavorable. In Chapter I we discussed some features of our environment; and as we have progressed in our study, we have learned how various plant and animal forms contribute to human welfare or retard it.

The term "environment," like that of heritage, is a broad one. It includes not only earth, air, water, and various living things, but also a great variety of influences which may be ours if we will. Among these we should include the school, the church, the government, the wealth of experience that has come down to us through the records of history, literature, art, music, and the achievements of science.

But unless we make the best possible use of these two factors, heritage and environment, real success in life will never be ours. It is true that we are not responsible in any way for the heritage we have received. We have also relatively little responsibility, at least during childhood and youth, for the environment in which we live. Each one of us, however, unless he is below normal in mental ability, rightly is held to a strict responsibility for the third factor in the triangle of life; namely, the *response* we make to the other two factors or, in other words, *what we do*. For example, one student in his high school course, even though his inheritance and his environment may not be of the best, wins success because he puts in his very best effort in training himself for life. For it is generally agreed that it is the successful effort put forth by the student that yields most in the educational process rather than the definite knowledge that may be acquired. On the other hand, another type of student fails in spite of good heritage and good environment because he persistently neglects the opportunities that come to him. Suppose we now consider somewhat more in detail each of these three factors that make or mar success.

388. Why heritage is of such great importance. In Part II we learned that each individual in the successive generations of higher living things is formed by the union of a sperm cell with an egg cell. We found that for this reason the offspring of plants and animals resemble the parent organisms from which the sperm cells and egg cells came. "Like produces like" is a general rule that applies throughout the world of living organisms. Race horses are descended only from other race horses. "It is blood that tells," whether in race horses or in human beings.

"The biologist holds," says Dr. Walter. "that, although what

an individual *has* and *does* is unquestionably of great importance particularly to the individual himself, what he *is*, is in the long run far more important. Improved environment and training may better the generation already born. Improved blood will better every generation to come." We are now to turn our attention to certain family histories, in which we shall find it strikingly true that heritage plays a dominating part.

389. Heritage in the Kallikak family. This absorbing tale of heredity [1] was worked out after long and patient investigation by Dr. Henry H. Goddard while he was Superintendent of the Training School for the Backward and Feeble-minded at Vineland, New Jersey. To that school in 1897 came a seven-year-old girl, who had been born in an almshouse. She had not done well in school and was difficult to control; hence she was put in the Vineland School.

When Dr. Goddard began to study the ancestry of this little girl, he soon found great difficulty, for apparently her relatives were of two entirely different types; namely, some who were well to do and highly intelligent and some who were poor and feeble-minded. At last the key to the puzzle was found way back in the time of the Revolutionary War in the person of a man to whom Dr. Goddard gave the fictitious name Martin Kallikak, senior (Kallikak is a combination of two Greek words that mean *good-bad*).

So far as is known (Fig. 352) Martin Kallikak's ancestors were all normal men and women. But in the Revolutionary War he was the father of a child whose mother was a feeble-minded young woman. This son, Martin Kallikak, junior, inherited the feeble-mindedness of his mother. He married, however, a woman who was more or less normal. Of the ten children of these two parents (father, feeble-minded; mother, normal), two died in infancy, *five were feeble-minded*, the mental condition of one could not be determined, and *only two were found to be normal!* A great deal has been learned regarding the history of 480 of the descendants of Martin Kallikak, senior, and the feeble-minded mother; some

[1] *The Kallikak Family*, by Dr. Henry H. Goddard.

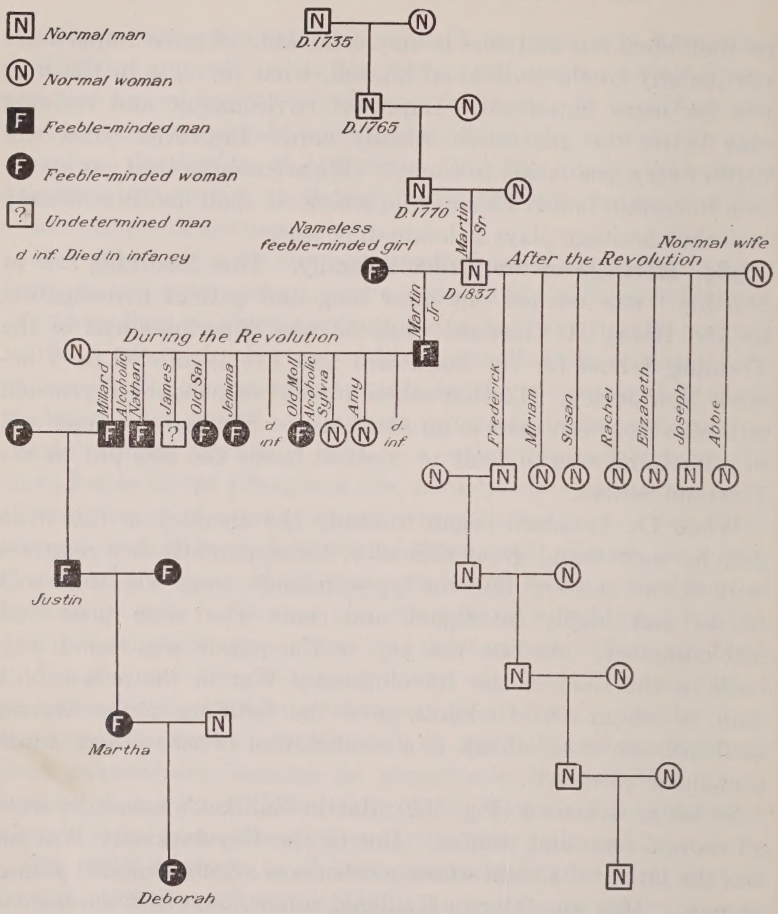


Fig. 352. — The Kallikak family

Of the 480 descendants of this branch of the family 143 (21%) were feeble-minded; only 46 (9%) were normal; of the rest 189 (68%) are still undetermined. 24 were confirmed alcoholics; 3 were criminals; 3 were epileptics; 82 died in infancy; 41 were degenerate.

Of the 496 descendants of this branch of the family, none were feeble-minded, and all were good citizens. Among them were doctors, lawyers, judges, educators, traders, landowners — men and women prominent in every phase of social life. Only 2 were alcoholic.

of the facts relative to their physical and mental condition are stated on the left side of Fig. 352. With such an ancestry as that represented on the chart, what possible success could be attained by poor little Deborah! Born in an almshouse she was brought to an institution for the feeble-minded at seven, there to remain, it is hoped, as long as she lives. This in brief is the dark side of the Kallikak story.

Let us turn now to the other side of this study in heritage. At the close of the Revolution Martin Kallikak, senior, married a Quaker girl of good ancestry and lived a respectable life after the traditions of his forefathers. Of this marriage seven children were born (see right side of the chart), and in all 496 descendants have been traced. All of these have been normal, good citizens except two, and of these not one was feeble-minded.

In both of these lines of descent, it should be remembered that the original ancestor (Martin, senior) is the same. The descendants of the two mothers have been traced in every kind of environment, and each of the two lines of children has always shown the characteristics of their respective mothers. Hence, we are forced to conclude that heritage was the controlling factor in the formation of their traits of character, and we are compelled to believe that feeble-mindedness is an hereditary characteristic. "In the cities," says Dr. Goddard, "the Kallikak descendants from the normal woman are physicians, lawyers, and prominent business men, while the descendants of the feeble-minded mother are almost invariably found in the slums. In the rural districts the descendants of the normal mother are wealthy and influential farmers, while the others never rise above the rank of day laborers and shiftless men and women, who are unable to subsist without the aid of charity. Many representatives of the defective branch are inmates of almshouses, while there are no paupers at all among the normal descendants."

390. What should be done with the feeble-minded. After a careful reading of the preceding paragraphs, it will hardly be necessary to emphasize the fact that feeble-minded, criminal, and diseased individuals, like those in the Kallikak family, should be

discovered early in life. They should be cared for at public expense in State institutions and thus should be prevented from transmitting to other generations their physical, mental, and moral weaknesses. Dr. Hart, Director of the Department of Child Helping of the Russell Sage Foundation, after a long experience in dealing with these problems, assures us that a few generations only would be required to eliminate from human society the feeble-minded and the socially diseased if mankind would only adopt the sane measures just suggested. Certain it is that every right-minded individual should avoid marrying into a family in which there is ancestral feeble-mindedness and should gladly coöperate with clergymen and others who refuse to join in marriage those who can not furnish physical — and mental — health certificates signed by reliable physicians.

391. Heritage in the Jonathan Edwards family. We now turn to a study of the lasting benefit that comes to the individual and to the race from children born of vigorous and highly intelligent parents. In striking contrast to the story of the branch of the Kallikak family descended from the nameless feeble-minded mother is the family history of Jonathan Edwards (Fig. 353), the most eminent preacher and thinker of New England in the early days of its history. Dr. Edwards had a remarkable ancestry; he married a wife with an equally remarkable heritage; and of his descendants Dr. Winship speaks as follows: "1394 of these descendants were identified in 1900, of whom 295 (more than one out of every five) were college graduates; 13 were presidents of our greatest colleges, besides many who were

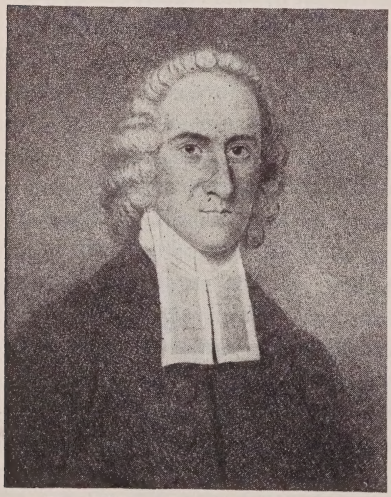


Fig. 353. — Jonathan Edwards

principals of other important educational institutions; 60 were physicians, many of whom were eminent; 100 and more were clergymen, missionaries, or theological professors; 75 were officers in the army and navy; 60 were prominent authors, by whom 135 books of merit were written and published and 18 important periodicals edited; 33 American states and several foreign countries have profited by the beneficent influence of their eminent activity; 100 and more were lawyers, of whom one was our most eminent professor of law (Prof. Woolsey of Yale); 30 were judges; 80 held public office, of whom one was Vice President of the United States (Aaron Burr); 3 were United States Senators; several were governors, members of Congress, framers of state constitutions, mayors of cities, and ministers to foreign courts; one was president of the Pacific Mail Steamship Company; 15 railroads, many banks, insurance companies, and large industrial enterprises have been indebted to their management. Almost every department of social progress and of public welfare has felt the influence of this healthy, long-lived family. It is not known that any one of them was ever convicted of a crime." [1] Any descendant of Jonathan Edwards may well be proud that such blood flows in his veins, for it is probably true that no other family has contributed more to our national welfare than has this.

392. The importance of a wise choice in marriage. One fact should be especially emphasized in the study of the Edwards family; namely, that in each of the various marriages both parents were individuals with healthy bodies, well-trained minds, and high moral characters. A young woman who wishes to marry a man for the sake of reforming him may possibly succeed in so doing although there is little evidence to show that this is probable. But even though she may succeed, she runs a grave danger of having her children burdened with the taint of disease or the traits of character which injured the father.

A great movement of the present day is that known as *Eugenics*, which is thus defined by the late Sir Francis Galton, who was so instrumental in its founding: "Eugenics is the science which

[1] Quoted from "Jukes-Edwards," by Dr. A. E. Winship, *New England Journal of Education.*

deals with all the influences that improve the inborn qualities of the human race; also with those that develop them to the utmost." We are slowly learning that any permanent improvement of the human race can only come as a result of better heritage.

393. Why education is of such great importance. Certainly enough has been said to show the tremendous consequences that come from good and from bad heritage. Most of us, however, belong to a great middle class, a class in which heritage is neither exceptionally good nor strikingly bad. For this reason, in order to win success, each one of us must do all in his power to make the two factors of environment and response count for all they are worth. Hence the great importance of getting a good education.

"Education is something more than going to school for a few weeks each year, is more than knowing how to read and write. It has to do with character, with industry, and with patriotism. Education tends to do away with vulgarity, pauperism, and crime, tends to prevent disease and disgrace, and helps to manliness, success, and loyalty. . . . A boy who leaves school and shifts for himself by blacking boots, selling papers, and 'swiping' fruit often appears much smarter than a boy of the same age who is going to school all the time and does not see so much of the world. A boy of twelve who has lived by his wits is often keener than a boy of the same age who has been well brought up at home and at school, but such a boy knows about as much and is about as much of a man at twelve as he will ever be; while the boy that gets an education becomes more and more of a man as long as he lives." [1]

394. Why self-activity is an essential condition for success. True success in life is not a gift that can be bestowed on another by anyone, no matter how rich or talented the would-be giver may be. It is something that must be won; and in order to win it, each individual must meet certain demands. For instance, that the body may be developed as perfectly as possible, suitable food and an abundance of fresh air must be supplied, and physical activities of different kinds must be engaged in. That the mind

[1] Quoted from "Jukes-Edwards," by Dr. A. E. Winship in the *New England Journal of Education.*

may be trained, it is important that the youth attend school and apply himself actively in the classroom. In all these activities he must heartily coöperate with the parent and the teacher if he is to become successful in the work he is to undertake in life whether that work is that of a physician, a lawyer, a merchant, a teacher, a skilled mechanic, or a leader of any sort. Why are all these activities essential?

In the human body there are five hundred separate muscles, and each of these muscles must be trained to do its share in the work of life. Now each muscle is controlled by the brain or by other parts of the nervous system (see Chapter XXVI), in which there are billions of nerve cells and fibers. All these nerve cells must be taught to coöperate, and this comes only as a result of long training.

Everyone knows that actions which are repeated again and again are carried out more effectively. The reason for this is that, by using repeatedly certain nerve and muscle cells, we are in a certain sense making beaten tracks through our bodies, just as a path through deep snow is finally made by the repeated tramping of feet. Training, whether in athletics, in mathematics, or in manual work, can only come by doing definite tasks over and over again. In this way *habits are formed* so that at length we seem to do a great many things, like walking, riding the bicycle, and playing the piano, without any conscious thought.

To win athletic success, a boy cheerfully lets cigarettes and sweetmeats severely alone, goes to bed early, and drives himself through weeks of tiresome training. So a girl who wishes to become a skilled pianist will practice hour after hour. Many school tasks seem irksome and useless; but if a youth is to succeed in school, in college, or in life, these tasks must be done; and the more cheerfully they can be performed, the better the training which is thereby secured.

It is most important that a youth seek the kind of training for which he is naturally adapted. Undoubtedly certain boys are better fitted for activities that bring into play the larger muscles rather than for taking the prescribed subjects of the high school

that prepare for the average college. Such boys should pursue the courses in agriculture, commercial branches, or technical science. For girls too there are many opportunities for special training that will fit them to win success in household science, clerical work, or technical pursuits. Too much emphasis can not be laid on the fact that only when boys and girls are absorbed in healthful pleasure or in useful pursuits are they safe.

395. Why habits are of supreme importance. Most people, when they speak of habits, seem to regard them as something to be shunned or deplored. True it is that a considerable number of human habits of thought and action belong to this class. As examples we may cite the habits of eating rapidly, of smoking by young people, of drinking intoxicating liquors, and of acting from motives of selfishness and greed.

As Professor James puts it, "The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time.' Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among his nerve cells and fibers the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is in strict scientific literalness wiped out." [1]

But in reality *habits are, or should be, our greatest friends and allies.* Suppose it were necessary for us to take conscious thought every time we took a step or wrote a word or struck a key on the piano! "A man might be occupied all day in dressing and undressing himself; the attitude of the body would absorb all his attention and energy; the washing of his hands, or the fastening

[1] Quoted from *Psychology* by William James.

of a button would be as difficult to him on each occasion as to the child on his first trial; and he would furthermore be completely exhausted by his exertions. Think of the pains necessary to teach a child to stand, of the many efforts which it must take, and of the ease with which it stands at last, unconscious of any effort." [1]

As a further example of the domination of everyday acts by the habits that are acquired, Professor James cites the following: "'Habit a second nature! Habit is ten times nature!' the Duke of Wellington is said to have exclaimed; and the degree to which this is true no one can appreciate as well as one who is a veteran soldier himself. The daily drill and the years of discipline end by fashioning a man completely over again as to most of the possibilities of his conduct." In the World War it was astonishing to see how soon the "rookies" who came into camp utterly unaccustomed to military discipline learned the routine, and then crossed the ocean to do their full share on the battlefields of France and Belgium.

396. The laws of habit formation. Since habits play such an important part in the lives of each one of us, how can we acquire those habits that make for our advantage and well-being? Can we find some general principles that will help us to make such habits our permanent possession?

In the first place, it is much easier to form habits in youth, when, as James says, "the nervous system is in the plastic state." Just as it is difficult to plow a new path through snow that has settled down and hardened, so too an adult finds it very difficult to acquire a new habit or to uproot an old one. It is for this reason that the home and the school become such important factors in habit formation. The parent and the teacher realize far more than can the growing boy or girl how vital to success in life are habits of neatness, of prompt obedience, and of honesty. And it is because of this knowledge that they labor so earnestly to make habits like these a part of the very being of those for whom they are responsible.

[1] Quoted from *Psychology* by William James.

Again, suppose we desire to form a new habit, like getting up promptly in the morning or showing real courtesy to our parents. What would be the effect of launching out upon the venture with as much vigor and enthusiasm as an athlete shows in training for a boat race or a ball team? If we keep everlastingly at it, even though like the athlete we are beaten now and then, what are the chances for final success? Is there any other way of plowing the right paths through our nerve cells that will mean success in the end? It is worth while to remind ourselves now and again that good resolutions are futile and powerless until they are translated into *action*.

Once more, it is most important to remember that *we must never make an exception* — never say, as did Rip Van Winkle, "I won't count this time" — in our new resolves, before the habit we have set out to acquire has become so firmly fixed in our nervous system that it has become second nature. In breaking a habit, like that of smoking for example, the same rule must be applied. It is surprising how soon a desire to do the wrong thing will die out if it is never fed.

And finally, we should remember that "the great thing in all education is *to make our nervous system our ally instead of our enemy*. For this reason we must make automatic and habitual as early as possible as many useful actions as we can, and guard against growing into ways that are likely to be harmful to us, as we would guard against the plague. The more of the details of our daily lives we can hand over to the effortless direction of habit, the more our higher powers of mind will be free for their own proper work," and so help to win the success for which we are striving.

"Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."

In the development of character close personal contact with

those who possess sterling qualities is of the first importance. Young people can not exercise too much care in the choice of associates both of their own age and those of larger experience in life. Most fortunate too is the young man or the young woman who has found safe anchorage in deep moral and religious convictions that are vital enough to fill and direct the whole life.

APPENDIX I

LABORATORY EQUIPMENT

The laboratory. It is very desirable that a definite room or rooms be set apart for work in biology, since at least a minimum equipment is essential, and this can not be transferred from room to room without considerable loss of efficiency. While it is desirable to have tables or at least flat-topped desks of good size, satisfactory laboratory work can be done in an ordinary classroom if it is well

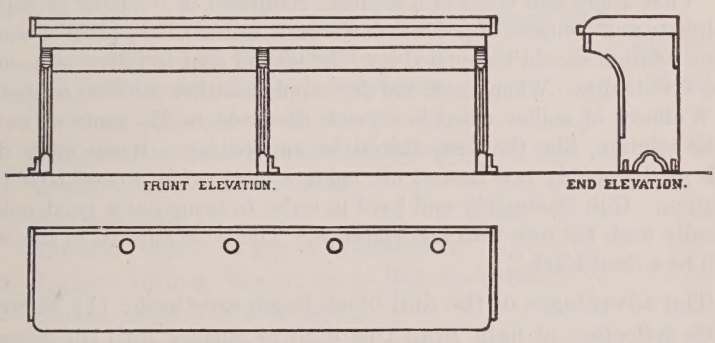


Fig. 354. — A plan for a laboratory desk

lighted. The laboratory should be supplied with a demonstration table and gas connection if possible, with sink and running water, and a broad shelf should be placed in front of the windows for supporting growing plants and aquaria and for use in demonstrations with the compound microscope. Ample closet room should be provided in which to store apparatus and supplies so that they may be kept free from dust.

In case it is possible to equip a room with laboratory tables the type shown in Fig. 354 is suggested. In the first place the laboratory tables should be firmly fixed to the floor and arranged so that the light comes from the left side and, if possible, also from the

back of the room. The desk tops should be 30 inches from the floor and 20 inches wide and should be made of maple or other hard wood. The length of each table will of course depend upon the dimensions of the room, but if possible no more than four pupils should be provided for at a single table. Each student should have at least 30 inches of the table space.

The finish of the laboratory table tops is a matter of importance, since it must be such as to protect the wood from damage and keep it clean and smooth. Many prefer a black finish, to obtain which the following method, used by the New York Board of Education, gives good results.

"First apply two coats of a solution composed of 5 ounces of copper sulphate and 5 ounces of potassium chlorate, mixed in 2½ pints of water. This solution should be applied hot, the second coat to follow as soon as the first is dry. When these are dry, apply another solution consisting of 6 ounces of aniline chloride crystals dissolved in 2½ pints of water. This solution, like the first, should be applied hot. When all is dry, rub in thoroughly raw linseed oil, using a cloth so as to secure a thin coating. Rub thoroughly and hard in order to bring out a good polish. Finally wash the tops with hot soapsuds. The table finished in this way will be a dead black."

The advantages of the dull black finish are these: (1) There is little reflection of light from this kind of surface into the eyes of the pupils; (2) the black surface furnishes an admirable background for many objects of study; and (3) the tops are not injured by water, acids, or other chemicals.

Experience has shown that unless the laboratory must be used as an assembly room for a division at the beginning and close of school, drawers and shelves beneath the desk are of little real use and often become mere receptacles for laboratory débris, unless they are provided with locks. It is usually far safer and more satisfactory to collect drawings, magnifiers, pencils, etc. at the close of the period and to distribute materials as they are needed during the next period. If this work is properly systematized and the assistance of pupils is made use of, very little of the laboratory time is lost in this way.

Apparatus and chemicals. — The following lists of apparatus and chemicals are suggested as a minimum equipment for a class of 24. Most of the items can be purchased from any one of the following dealers:

Central Scientific Co., 460 East Ohio St., Chicago, Ill.
Kny-Scheerer Co., 119 Seventh Ave., New York City.
E. Leitz, 60 E. 10th St., New York City.
Will Corporation, Rochester, N. Y.

Quantity	Apparatus and Glassware	Estimated Price
1	Compound microscope, with $\frac{2}{3}$- and $\frac{1}{6}$-inch objectives, double nosepiece, 1 inch eyepiece, and revolving disk diaphragm	$69.50
24	Magnifiers, doublets, $1\frac{1}{2}$-inch focus	36.00
1	Harvard trip-scale balance	9.00
2	Evaporating dishes, 3 inches diameter	.48
1	2-quart agate double boiler	2.50
1	Alcohol lamp *or*	.40
1	Bunsen burner (if gas is available)	.50
3 ft.	Rubber tubing (heavy) to fit Bunsen burner	.30
144	Slides, plain, 1 × 3 inches	1.40
1 oz.	Cover glasses (round)	1.50
24	Forceps (heavy)	10.00
12	Dissecting scissors	6.00
50	Handles (adjustable) for dissecting needles	6.50
100	Needles for handles	1.50
144	6-inch test tubes	2.50
12	8-inch test tubes, hard glass	3.00
2	Chemical thermometers (Fahrenheit and centigrade scale on same)	2.50
1	Radiometer	3.00
2	Iron ring stands (3 rings)	2.60
2	Pieces wire gauze (4 × 4 inches)	.20
2	Pieces asbestos (4 × 4 inches)	.14
6	Glass stirring rods	.25

Quantity	Apparatus and Glassware	Estimated Price
25 ft.	Glass tubing, 5 mm. outside	$ .50
10 ft.	Rubber tubing to fit glass tubing	.75
12	Thistle tubes (medium size)	1.20
12	Beakers, 150 to 250 cc.	2.25
2	Bell jars 2 feet high and 10 inches in diameter	16.00
2	Bell jars about 8 inches high and 10 inches in diameter	10.00
1 piece	Sheet rubber 2 feet square (should be kept in lightning fruit jar when not in use)	.80
24	Lightning fruit jars (1 quart)	3.10
6	Flasks, 250 cc.	1.32
36	Petri dishes, 4 inches in diameter	8.10
1	Cylindrical graduate, 1000 cc.	1.60
1	Cylindrical graduate, 100 cc.	.50
2	Tall glass cylinders (1000 cc.)	1.80
1	Box slide labels	.10
1	Box labels, 2 × 3 inches	.30
1	Steam sterilizer, copper bottom, 18 inches high	15.00
24	8-ounce wide-mouthed bottles	2.30
24	4-ounce wide-mouthed bottles	1.70
50	Vials with corks, 3 inches high, 1 inch in diameter	2.00
100	Corks to fit 8-ounce wide-mouthed bottles	2.00
100	Corks to fit 4-ounce wide-mouthed bottles	.50
100	Corks to fit 6-inch test tubes	.40
10	Rubber stoppers with 2 holes to fit 250-cc. flasks	.50
10	Rubber stoppers with 1 hole to fit 6-inch test tubes	.35
2	Insect spreading boards	2.40
12	Battery jars, 6 inches in diameter, 8 inches high	6.00

Quantity	Charts and Preparations	Estimated Price
7	Jung plant charts (pansy, tulip, potato, carrot, pea, mold, fern)	$19.25
9	Jung animal charts (fish (external), fish (internal), frog, Amœba, Paramecium, crayfish, bee, butterfly)	24.75

Quantity	Charts and Preparations	Estimated Price
4	Leuckhart animal charts (grasshopper, bee, butterfly, metamorphosis of frog)	$18.00
1	Model of heart and lungs (dissectible), natural size	18.00
1	Model of digestive system on panel, natural size	18.00
1	Model of circulatory system on panel, natural size	15.00
1	Articulated human skeleton, clutch standard	85.00
1	Life history of butterfly	2.00
1	Life history of honeybee (in case)	3.00
1	Life history of frog	7.50
1	Life history of fish	7.50
1	Half-skeleton of fish (glass case)	15.00
1	Half-skeleton of frog (glass case)	8.00
8	Microscopical slides of plant tissue (cross section and longitudinal section of young root, cross section and longitudinal section of stem one year old, cross section of hydrangea leaf, epidermis of leaf, separate wood cells, ducts)	4.55
5	Microscopical slides of animals (Amœba, Paramecium, frog's blood, human blood)	3.75

Quantity	List of Chemicals	Estimated Price
2 lb.	Hydrochloric acid	$1.00
1 lb.	Nitric acid	.60
1 lb.	Ammonia	.50
1 oz.	Iodine	.55
5 oz.	Potassium iodide	2.30
1 lb.	Ether	.40
1 lb.	Caustic soda	.50
1 gal.	Denatured alcohol	5.00
10 lb.	40 per cent formalin	3.25
8 oz.	Glycerin	1.10
1 oz.	Pepsin	.35
1 lb.	Peptone	2.20
1 oz.	Taka diastase	2.30

Quantity	List of Chemicals	Estimated Price
1 lb.	Salt	$ .16
5 oz.	Phosphate of lime	.30
1 lb.	Grape sugar	.75
½ lb.	Cooking soda	.10
1 lb.	Copper sulphate	.35
1 lb.	Rochelle salt	.40
1 jar	Beef extract	1.50
1 lb.	Agar	2.75
½ lb.	Powdered sulphur	.25
1 lb.	Potassium chlorate	.40
½ lb.	Manganese dioxid	.50
1 lb.	Granulated zinc	.50
1 lb.	Absorbent cotton	.75
6	Small candles	.20
1 lb.	Marble pieces	.25
1 oz.	Ferric chloride	.20
1 lb.	Corn starch	.25
½ lb.	Arrow-root starch	.30
1 oz.	White egg albumen	.25
1 oz.	Powdered carmine	.55
1 oz.	Gluten	.70
½ lb.	Sodium nitrate	.30
½ lb.	Potassium nitrate	.35
½ lb.	Calcium sulphate	.25
1 lb.	Sodium citrate	1.20
1 lb.	Sodium carbonate (anhydrous)	.40

APPENDIX II

DIRECTIONS FOR MAKING SOLUTIONS, APPARATUS, AND PREPARATIONS

Preparation of oxygen. Thoroughly mix a teaspoonful of potassium chlorate with about one fourth as much black oxid of manganese. Put the mixture in a large test tube. Close the mouth of the test tube with a stopper through which passes a delivery tube, the other end of which runs beneath the surface of water in a tray. Support the test tube in a slanting position on an apparatus stand and heat the mixture with a gas or an alcohol flame, until the oxygen begins to be given off. Fill three or four bottles with water, cover each with a piece of glass or cardboard, and invert the first one over the mouth of the delivery tube, removing the cover when the mouth is under water. Continue to heat the mixture until the bottle is full of oxygen, then cover it under water with the glass plate or cardboard, and stand it right side up on the table. In the same way fill as many jars with oxygen as are needed for the experiments (Fig. 11).

Preparation of iodine solution. Dissolve in 5 teaspoonfuls (40 cc.) of water one half a teaspoonful (4 grams) of potassium iodide and one fourth this amount of iodine (1 gram). This solution, when thoroughly mixed, should be diluted to make one quart (1000 cc.). In a clean bottle this mixture will keep indefinitely.

Preparation of Benedict's solution. By using heat dissolve 173 grams of sodium citrate and 100 grams of sodium carbonate (anhydrous) in about 600 cc. of water. Pour the solution through filter paper into a glass graduate and add enough (distilled) water to make 850 cc. Dissolve 17.3 grams of copper sulphate in about 100 cc. of water, and add distilled water to make 150 cc. Pour the sodium citrate and sodium carbonate solution into a large

beaker or battery jar and add the copper sulphate solution slowly, stirring constantly.

Preparation of Fehling's solution. Dissolve 3 teaspoonfuls (34.64 grams) of pure pulverized copper sulphate (blue vitriol) in a little less than half a pint of water (200 cc.). Make a second solution by dissolving in a pint (500 cc.) of water twelve heaping teaspoonfuls (150 grams) of Rochelle salt and 3 (5-inch) sticks of caustic soda (50 grams). Fehling's solution does not keep for any great length of time and hence must be made up fresh a short time before it is needed. To do this, thoroughly mix two volumes of the copper sulphate solution and five volumes of the solution of Rochelle salt and caustic soda and dilute the mixture with an equal volume of water. It is more convenient to prepare it in small quantities from tablets that may be obtained of druggists. Before making any tests boil a small quantity of the Fehling's solution in a clean test tube. If it retains its transparent blue color, it is ready for use; otherwise a fresh supply must be prepared.

Preparation of root hairs. Cover the bottoms of as many Petri dishes as are needed with a layer of blue blotting paper (Fig. 86). Soak the paper with water and lay several grains of soaked barley, oats, or corn upon the bottom of each dish. Put the covered dishes in a warm place for several days. When the root hairs have developed, wipe the moisture from the inside of the covers, quickly replacing the latter. If Petri dishes are not available, two clean glass plates of any convenient size may be used instead. Cover one of the plates with layers of wet blotting paper, put the soaked grains in position, and cover with the second glass, fastening the two together with threads or strings. Stand one end of the preparation thus made in a jar with enough water to reach the lower edge of the blotting paper.

Preparation of culture dishes for raising bacteria. To prepare 1000 cc. (about a quart) of agar mixture, weigh out 10 grams of salt, 10 grams of peptone, 10 grams of Liebig's beef extract, and 10 grams of agar. Measure into an agate stewpan 1000 cc. of water, and stir in the salt, peptone, beef extract, and agar (the latter having been cut into small pieces). Heat the mixture

in a double boiler until the agar is wholly melted. Slowly stir in just enough baking soda to cause red litmus paper to turn blue (*i.e.* the mixture should be *slightly* alkaline). When the pieces of solid agar have all disappeared, the hot liquid should be filtered into flasks of 250 cc. capacity through several rather thick layers of absorbent cotton placed in a funnel. This filtration might well be done by placing the flasks in a steam sterilizer. If the filtrate is not clear, the liquid should be poured through the same layers of cotton till it does become clear. Care should be taken to keep the agar mixture hot during the filtering process; otherwise the agar will not pass through the cotton. When the flasks are nearly full, plug the mouth of each with a large wad of cotton batting, put them into a steam sterilizer, and heat them at least thirty minutes on each of three successive days to make sure that all germs and their spores are killed. The flasks of agar may then be kept as a stock mixture until needed.

Carefully clean and dry enough Petri dishes to supply, if possible, ten or more dishes for experiments with each division of students. Put the closed dishes in an oven and heat to a high temperature (150° C.) for an hour to kill any germs or spores that may be on the dishes. Allow the oven to cool before opening the door; otherwise the dishes are likely to crack.

To fill the Petri dishes, melt the agar mixture in a steam sterilizer; then arrange the sterilized Petri dishes along the edge of a horizontal surface. Carefully remove the cotton plug from the flask, lift one edge of the cover of one of the Petri dishes, pour enough of the hot agar mixture into the lower part of the dish to make a layer about an eighth of an inch deep, and quickly replace the cover on the dish. Quickly pour into each of the dishes in turn. After the agar has hardened, the dishes are ready for the experiments. Any agar mixture left in the flasks should be sterilized for thirty minutes on each of three successive days in order to make sure that it will keep for subsequent use.

In general it is far more satisfactory to secure nutrient agar ready-made. City Boards of Health are usually glad to coöperate with biology teachers in this way.

Insect net. Since most butterflies and moths are more or less injurious, at least in their caterpillar stage, boys and girls should be taught that they are benefiting their community by catching and killing these insects in a painless manner. For this purpose an insect net and a poison bottle are necessary. One can make an insect net by securing a yard of galvanized iron wire (No. 3), bending it in the form of a ring (thus ♌), and inserting the two ends of the wire in one end of a light wooden rod about three feet long. To the wire ring should be sewed a bag about two feet deep made of cheesecloth or bobbinet (Fig. 355). To catch a butterfly or other insect, wait until it alights, then quickly place over it the opening of the net, holding up the closed end of the net till the insect flies to the top. Now place beneath the insect the open mouth of an insect bottle (Fig. 356); and after the insect is in the bottle, quickly replace the cover.

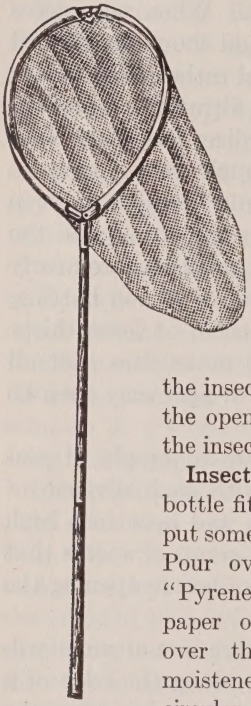


Fig. 355. — An insect net

Insect bottle. Secure a pint fruit jar or a wide-mouthed bottle fitted with a stopper (Fig. 356). Into the bottom put some crumpled pieces of blotting paper or some cotton. Pour over this enough carbon tetrachloride (used in "Pyrene" fire extinguishers) to moisten thoroughly the paper or cotton. Put over the top of this moistened material a circular piece of paper. The bottle should be kept tightly closed when not in use, and should be labeled, "Insect Killing Bottle." These bottles are perfectly safe in the hands of pupils.

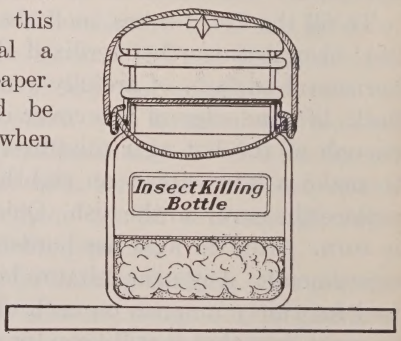


Fig. 356. — Insect killing bottle

Preparation of butterflies for study or for collections. For laboratory study it is desirable to use the largest butterflies obtainable. If possible, one mounted specimen for each two pupils should be prepared with the wings fully extended, with the legs spread out as in

walking, and with the proboscis partly uncoiled. To get the material in this shape place two books about half an inch apart on a soft board; run an insect pin through the thorax of a freshly killed insect, extend the legs and proboscis, then put the body of the insect between the two books, thrusting the tip of the pin into the board beneath. Spread out the fore wings on the book covers so that their hind margins are at right angles to the thorax, pull the hind wings outward into their natural positions when at rest, and hold the two pairs in place with pieces of glass till the specimen has dried. Butterfly spreading boards may be bought or made (Fig. 357).

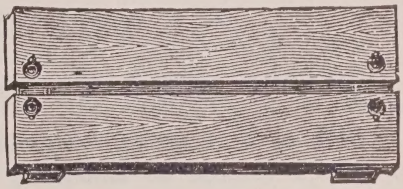


Fig. 357. — An insect spreading board

Dry specimens may be relaxed by placing a quantity of sand or crumpled paper in a battery jar or other wide-mouthed receptacle that can be tightly covered. Wet the sand or paper thoroughly and then sprinkle over it a little dry sand or cover with blotting paper.

Put in the dried butterflies about twenty-four hours before they are to be spread, and cover the receptacle. If the relaxing jar is kept in a warm place, the process will be hastened, but care should be taken not to leave the insects in the moist chamber long enough for mold to grow upon them. It is of course better to mount the butterflies as soon as they are killed.

APPENDIX III

BIOLOGY NOTEBOOKS AND REFERENCE BOOKS

Method of recording laboratory observations. In preparing notebook records of laboratory observations or experiments, home work, or field trips, the teacher should insist, so far as possible, that pupils give in clear, concise English a complete account of the work that has been done. The student should carefully state the purpose of the experiment and describe the preparation of the experiment. He should indicate whether the work was done by himself or by some one else. The results observed should be sharply distinguished from the conclusions derived from observation.

Drawings. In making drawings pupils should be supplied with sharp-pointed pencils that are relatively hard. Clear outline drawings should be insisted upon, and shading should as a rule not be encouraged. The general title of the sheet of drawings should be placed at the top of the sheet. When there are several drawings on the same sheet, the general title should be placed at the top, and the special title of each should be written just below the individual drawing. In labeling, the dotted leaders may run in various directions, but they should not cross each other. The labels, however, should all be written parallel to the top margin of the sheet. If the drawings are made on separate sheets of paper about the size of a page in the notebook, the sheets may be collected, criticized, and rated, and then, if the left-hand margin of about an inch is folded, the drawings can be fastened in the notebook by pasting this narrow flap.

The following directions for guiding pupils in the preparation of their notebooks have been found by the authors to be of great assistance.

1. In the upper right-hand corner of the outside front cover

of your notebook write your name, division (*i.e.* grade and section), and the official classroom in which you meet.

JOHN S. JONES, I–8 (or IA)
Room 416

Across the middle of the front cover write BIOLOGY NOTEBOOK.

2. Write your name, division, and classroom in the upper right-hand corner of the first page of your notebook. Leave the rest of the page blank for the teacher's ratings and comments.

3. Number each page of your notebook.

4. On each of the pages draw a vertical line about an inch from the left margin. Always leave this marginal space for the teacher's comments.

5. Begin each new subject or experiment on a new page, writing its title on the first line. The first composition or notes should commence on page 5, the preceding pages being reserved for index.

6. Write your compositions or notes in ink on both sides of the page.

7. Indent about an inch the first word of each paragraph. All other lines should begin at the left margin line.

8. Make sure that your statements in each paragraph or in your notes are sufficiently full and clear to be readily intelligible to one who knows nothing of the subject.

9. In your compositions or notes be careful to make clear what you yourself *did,* what you *saw,* what you *heard,* and what you *read.* Accounts of experiments may often be written in four paragraphs as follows: object of experiment; preparation of experiment; result of experiment; conclusion from experiment.

10. If, on account of absence, it is necessary that work be copied, inclose such account in quotation marks, and write at the end of such quotation the name of the pupil from whom the account was copied.

11. Every correction indicated by the teacher should be made by the student as soon as the notebook is returned.

12. Every student who wishes to do so can produce a first-class notebook, neat in appearance and at least relatively free from mistakes in spelling, punctuation, and grammar.

MARKS USED IN THE CORRECTION OF BIOLOGY PAPERS

cp = mistake in use or in omission of capital letter.
cl = meaning not clear.
gr = mistake in grammar.
n = composition lacking in neatness.
¶ = error in paragraphing.
p = mistake in punctuation.
r = repetition of word or idea.
sp = error in spelling.
w = word improperly used.
? = doubt as to the truth of the statement.
( ) = words in parenthesis are to be crossed out.
^ = some omission.

SUGGESTED LIST OF REFERENCE BOOKS FOR TEACHERS

ARMSTRONG, MARGARET — *Field Book of Western Flowers;* G. P. Putnam's Sons.

BAILEY, L. H. — *Manual of Gardening;* The Macmillan Co.

BILLINGS, JOHN S., AND OTHERS — *Physiological Aspects of the Liquor Problem* (2 vols); Houghton Mifflin Co.

BRITTON, N. L., AND BROWN, ADDISON — *An Illustrated Flora of the Northern United States, Canada, and British Possessions* (3 vols.); Charles Scribner's Sons.

BUCHANAN, E. D., AND R. E.—*Bacteriology for Students in General and Household Science;* The Macmillan Co.

BURTON-OPITZ, RUSSELL — *Elementary Physiology;* W. B. Saunders Co.

CALDWELL, OTIS W., AND SLOSSON, EDWIN E. — *Science Remaking the World;* Doubleday, Page & Co.

CANNON, WALTER B. — *Bodily Changes in Pain, Hunger, Fear, and Rage;* D. Appleton & Co.

CHAPMAN, FRANK M. — *Bird Life;* D. Appleton & Co.

CHAPMAN, FRANK M. — *Handbook of Birds of Eastern North America;* D. Appleton & Co.

COULTER, JOHN M., BARNES, CHARLES R., COWLES, HENRY C. — *Textbook of Botany* (2 vols.); American Book Co.

DOWNING, ELLIOT R. — *The Third and Fourth Generation;* The University of Chicago Press.

DUGGAR, B. M.—*Plant Physiology;* The Macmillan Co.

EDDY, WALTER H. — *Vitamine Manual;* Williams & Wilkins Co.

FORBUSH, EDWARD H. — *Useful Birds and Their Protection;* Massachusetts Board of Agriculture.

GAGER, C. STUART — *Fundamentals of Botany;* P. Blakiston's Son & Co.

GODDARD, HENRY H. — *The Kallikak Family;* The Macmillan Co.

HARROW, BENJAMIN — *Glands in Health and Disease;* E. P. Dutton & Co.

HARWOOD, W. S. — *The New Earth;* The Macmillan Co.

HEGNER, R. W. — *College Zoology;* The Macmillan Co.

HOLMES, S. J. — *Biology of the Frog;* The Macmillan Co.

HORNADAY, W. T. — *American Natural History;* Chas. Scribner's Sons.

HORNADAY, W. T. — *Minds and Manners of Wild Animals;* Chas. Scribner's Sons.

HOUGH, THEODORE, AND SEDGWICK, WILLIAM T. — *The Human Mechanism;* Ginn & Co.

HOWARD, L. O. — *The Insect Book;* Doubleday, Page & Co.

HOWELL, WILLIAM H. — *Physiology;* W. B. Saunders Co.

JEWETT, FRANCIS GULICK — *The Next Generation;* Ginn & Co.

JORDAN, DAVID STARR, AND EVERMANN, BARTON W. — *American Food and Game Fishes;* Doubleday, Page & Co.

KELLY, HENRY A. — *Walter Reed and Yellow Fever;* Norman Remington Co.

LEE, ROGER I. — *Health and Disease;* Little, Brown & Co.

LOCY, WILLIAM A. — *Biology and Its Makers;* Henry Holt & Co.

LUTZ, F. E. — *The Field Book of Insects;* G. P. Putnam's Sons.

MARSHALL, CHARLES E. — *Microbiology;* P. Blakiston's Son & Co

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[Roman figures refer to pages. Black-face figures (*e.g.* **145**) refer to pages on which illustrations occur.]

KEY TO MARKS OF PRONUNCIATION

ā as in āle, **å** as in senåte, **â** as in câre, **ă** as in ăm, **ă̈** as in ă̈ccount, **ä** as in ärm, **à** as in àsk, **ȧ** as in sofȧ; **ē** as in ēve, **ȩ̄** as in ȩ̄vent, **ĕ** as in ĕnd, **ĕ̈** as in recĕ̈nt, **ę̄** as in makę̄r; **ī** as in īce, **ĭ** as in ĭll; **ō** as in ōld, **o͝o** as in o͝obey, **ô** as in ôrb, **ŏ** as in ŏdd, **o͡o** as in co͡onnect; **ū** as in ūse, **u͝u** as in u͝unite, **û** as in ûrn, **ŭ** as in ŭp, **u͡u** as in circu͡us, **ü** as in menü (hold the lips as if to pronounce o͝o and try to say ē); **o͝o** as in fo͝od, **o͡o** as in fo͡ot; **ou** as in out; **oi** as in oil; **ch** as in chair; **g** as in go; **ng** as in sing; **ĸ** as the "ch" in German word ich (half-way between the sound of "k" and "sh").

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